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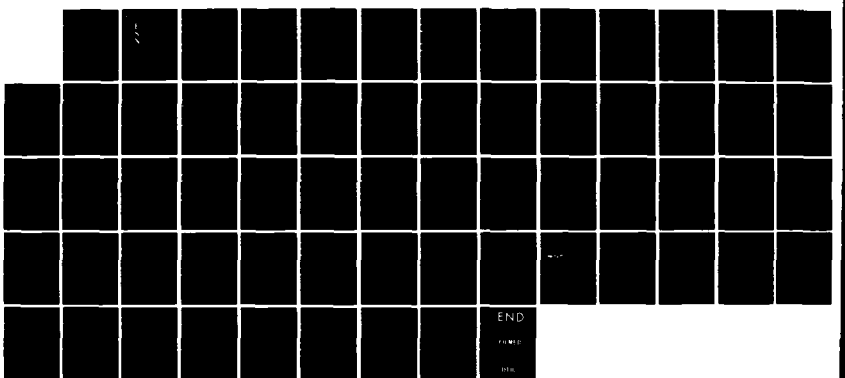

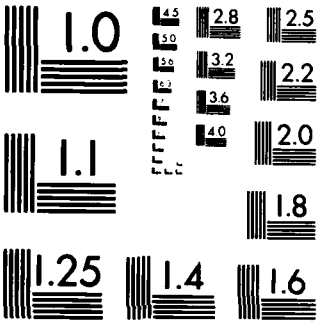


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# European Science Notes

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European Science Notes (ESN) is a monthly publication with brief articles on recent developments in European scientific research. The publication is not intended to be part of the scientific literature. The value of ESN articles to Americans is to call attention to current developments in European science and technology and to the institutions and people responsible for these efforts. ESN authors are primarily ONRL staff members. Occasionally articles are prepared by or in cooperation with staff members of the USAF European Office of Aerospace Research and Development or the US Army Research, Development and Standardization Group. Qualified US scientists travelling in Europe may also be invited to write an ESN article.

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# European Science Notes

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## Behavioral Sciences



## Biological Sciences

The Biomaterials Department in the School of Dentistry at the Free University of Amsterdam has an active and innovative group of researchers. One of the group's primary activities is the search for an ideal bone-substitute material. The scientists are also doing research on the controlled release of drugs using polyphosphazenes.

## Computer Sciences



The Declarative Systems Research Group at Imperial College, London, has developed a comprehensive philosophy of the dominating role of deductive reasoning in fifth generation computing. Intensified external support is speeding up a variety of new basic-research projects.



Researchers at the UK's Southampton University are planning to build a supercomputer using the Transputer manufactured by INMOS Ltd. The system's flexible architecture is expected to have applications in scientific computing, in which very high speed is essential.

## Material Sciences



The Welding Institute is probably the best organization of its kind in the free world. It is a center for professional qualification, practical training and education, research, and support to the UK industries involved in fusion welding and other joining techniques. This article surveys the work of the institute's Research Division, Sheet and Precision Processes Division, and Materials Division.



The welding research at the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF) is more fundamental than most welding research in Europe. Nonetheless, it is guided by industrial needs. This article examines research on hyperbaric welding, the implant test, and weld-metal chemsitry.

## Mathematics



Researchers at the University of Leiden are doing important work on the modeling and analysis of nonlinear diffusion-reaction processes. This article discusses the reasons for studying such problems and examines two classes of phenomena investigated at Leiden.

The Center for Mathematics and Computer Science (CWI) in Amsterdam does an excellent job of combining basic research with applications. It has recently received stimulation grants to transfer advanced mathematics to Dutch industries and government agencies. This article provides an overview of the center's work, focusing particularly on research in numerical analysis.

## Mechanics



The Statens Skeppsprovningsanstalt (SSPA) and the firm KaMeWa are using modern water-tunnel techniques for dynamic hull-propeller interaction studies. KaMeWa is also noted for its excellent controllable-pitch propeller production. Swedish experience in tests of hull and propeller models together with cavitation scaling is providing guidance to US water-tunnel developments.

## Physics



Frankfurt is an unusually vigorous center for laser development, quantum optics, nonlinear phenomena studies, and solid state electro-optics. The Battelle Institute and several (both experimental and theoretical) groups at the university have scored a number of "firsts" in these areas. This article reports on current highlights of research at these institutions.



The University of Tübingen's Institut für Informationsverarbeitung has major research groups in information technology and in system theory and synergetics. This article focuses on the system-theory work in the following areas: structure formation, recognition of structures, optical bistability and self-pulsing, and inverse scattering in remote sensing.



The Institute of Physics of the Bundeswehr University in Munich, West Germany, is doing high-quality work in two areas of interest to the US Navy: (1) optically generated thermal waves and optoacoustic detection and regulation, and (2) microelectronics device fabrication and theoretical studies of metal-oxide-semiconductors and superlattice devices.

## Space Sciences



The UK has completed the latest node in its Starlink computer network, which is primarily intended for the use of astronomers in analyzing observational data emphasizing the interactive processing mode. In addition, new telescope observing facilities at remote installations outside the UK have been completed or are under construction.

# News and Notes



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# Behavioral Sciences

## EDUCATIONAL SCIENCES AND TECHNOLOGY: A NEW APPROACH TO TEACHING SCIENTIFIC PROBLEM SOLVING

*by Richard E. Snow. Dr. Snow is the Liaison Scientist for Psychology in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until September 1985 from Stanford University, where he is Professor of Education and Psychology.*

Twente University of Technology's emphasis on educational sciences and technology has fostered a program of research and development on the teaching and learning of problem solving in science. Its Center for Educational Research and Development includes a team of physical scientists and educational researchers who have collaborated to develop and improve science instruction in the university. Their work, however, makes a more general contribution to cognitive instructional psychology as well.

Anyone with experience in teaching science knows the difficulties students have in learning to solve problems using the concepts, laws, and formulas of the subject matter they are studying. Students often do not know how to organize their attack on a new problem. Some use trial and error, some memorize the textbook problems, some wait for hints from the instructor; they hope to pass examinations by recognizing familiar problems they already have learned to solve, rather than by assembling strategies to confront new problems. Students also, of course, come to new learning with all sorts of partial, bookish conceptions and misconceptions. The task for instruction in science is to build both declarative and procedural knowledge and, most importantly, to develop an integration of the two that provides flexible strategies for solving both the well-structured and the not-so-well-structured problems typically faced in science.

Over recent years, the Twente team has developed a systematic approach to this problem. It includes a set of principles of instructional learning to be used in course development and a "Program of Actions and Methods" (or PAM) for solving problems. This in turn leads to systems of heuristics known as SAP-charts, where "SAP" stands for "Systematic Approach to Problem Solving." An example of a SAP-chart is shown in Figure 1. The group has now used this approach to develop experimental courses for a variety of topics in physics and chemistry (e.g., thermodynamics, electromagnetism, mechanics) as well as in other fields. They have also computerized the system for inclusion in computer-aided-instruction courses. Several overview papers have appeared in English (Mettes, Pilot, and Roossink, 1981; Mettes, Pilot, Roossink, and Kramers-Pals, 1980, 1981; Kramers-Pals, Lambrechts, and Wolff, 1980, 1982; van Weeren, De Mul, Peters, Kramers-Pals, and Roossink, 1982; Pilot, van Weeren, Mettes, and Staal, n.d.). Detailed technical reports and instructor handbooks are also available in Dutch (Mettes and Pilot, 1980; Terlouw, Mettes, and Roemers, 1981; Mettes and Roossink, 1982; DeJong and DeZwart, 1983).

The theoretical principles for instructional learning are based in Soviet psychology, primarily in the theory of Gal'perin and its extensions (see De Corte, 1980; Talyzina, 1973; Landa, 1975). In brief, learning is seen as the acquisition of new mental actions, so instructional learning is a process of planned progressive internalization of external actions. The stage-by-stage formation of new mental actions starts with an orienting stage in which the learner is given the complete information necessary for a perfect performance, including the goal, the composition of all action links, and the conditions under which the action can and cannot be performed.

The learner then performs the complete action in a materialized form, to be observed and corrected by learner and teacher together. Mastery in this form is followed by practice to mastery in progressively less materialized and more mental forms. Mastery in mental form should be clearly transferable, abbreviated, and automatic. Most of the actions learned concern use of particular algorithms and heuristics. There is also emphasis on the systematization in operational form of all declarative and procedural knowledge relevant to particular kinds of problem solving. A strength of the approach lies in its explication of procedural strategies that are often left implicit in formal instruction and thus remain unknown to learners and perhaps even to many teachers.

The first target for study was thermodynamics. Through extensive preliminary studies and formative evaluations, Mettes and Pilot and their collaborators collected various kinds of quantitative and qualitative data, including "think aloud" protocols of

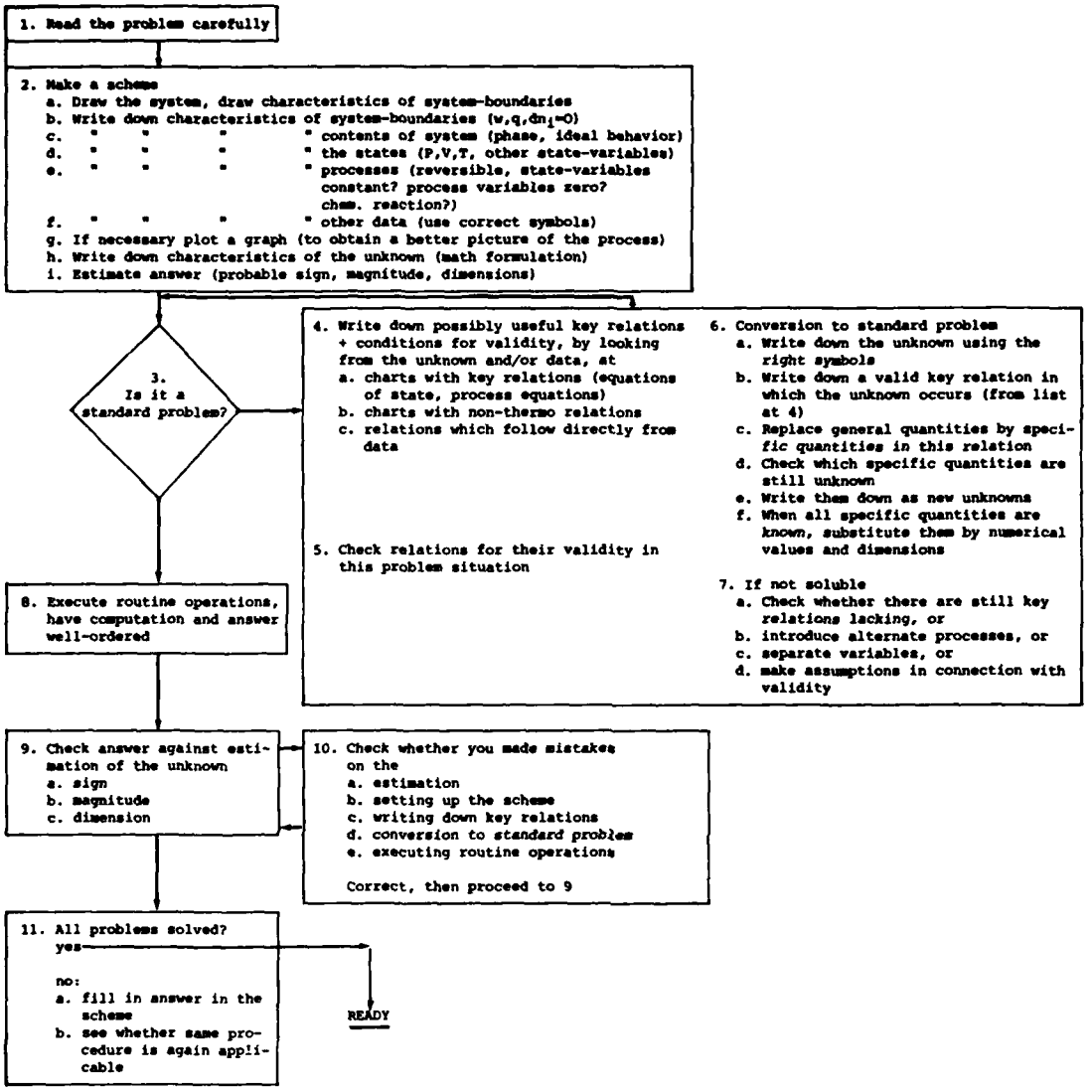


Figure 1. SAP-chart.

students and instructors solving the sorts of problems typically faced in science courses; these were examined together with both the US and Soviet cognitive psychological literature on problem solving, and the general literature on heuristics. The aim was to develop through analyses of all this as complete a set of prescriptions for action in problem solving in thermodynamics as possible. This analysis provided a PAM for this particular course.

To translate the PAM specifications into a form suitable for student use, the SAP-chart technique was developed, using various principles governing the heuristics to be included, the language to be used, the completeness of description, etc., to ensure that a SAP-chart could serve as a guide to a complete action in materialized form, as the Gal'perin theory requires. The chart in Figure 1 is an abstracted example. See Mettes, Pilot, and Roossink (1981) for more detailed examples of both PAM and SAP.

In a sense, the PAM is an elaborated statement of the goal of instruction--a theory of what is to be achieved, one could say. It was thus necessary to map the parts of this goal into a matrix that crosses instructional functions with particular instructional procedures or means. Examples of this step

and the course developments that resulted are given by Mettes, Pilot, and Roossink (1981). They also summarize instructional experiments in which contrasts on various measures show the clear superiority of experimental over control versions of this course.

Various generalizations derived from this experience have been carried into research and development with other science courses at Twente, with continuing success. Although the research completed to date has not answered some of the longer term questions typically asked of instructional research, such as whether individual students succeed in transferring their acquired problem-solving skills to other problem domains, or whether such a course is particularly well suited or poorly suited to students with particular kinds of aptitude profiles, the evidence available so far is impressive. The approach clearly deserves considerable further research attention. Meanwhile, in Twente, it is becoming the design for an increasing number of science and technology courses.

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*3/25/85*

## EDUCATIONAL SCIENCES AND TECHNOLOGY: A NEW SPECIALIZATION IN THE NETHERLANDS

*by Richard E. Snow.*

The rapid growth of new information technologies (NIT) is creating short-term and long-term demands on the educational systems of most industrialized nations. In turn, a critical concern is the adaptation of education to NIT, both to meet national needs for NIT specialists and to use NIT to improve education across the board. A previous article (*ESN* 39-5:179-183 [1985]) described some of the policy issues identified through surveys of the problem in France, Sweden, and West Germany. The present article reports on a relevant Dutch initiative.

In brief, three issues stand out at the intersection of NIT, education, and industrial training needs:

1. How to use NIT to improve school-based education at all levels and

to increase computer literacy in the student population generally.

2. How to improve education, particularly in the sciences, mathematics, and technologies needed as preparation for advanced training in NIT specialities.

3. How to improve industry-based training in NIT-related fields and its links with the school-based educational system.

Underlying all these issues is the need to harness what has been and can be learned from research in psychology, education, and related social sciences to the task of instructional improvement.

Twente University of Technology in Enschede, The Netherlands, and its innovative new department of Educational Sciences and Technology is at the center of the Dutch attack on these issues and needs. Twente was founded in 1962 as the third Dutch technical university (the two older institutions are in Delft and Eindhoven). Its primary emphasis has been in mechanical, chemical, and electrotechnical engineering, physics, and mathematics; students could also choose an extra concentration in business administration. In the 1970s, the government decided to add two applied social science emphases that would be closely allied with the science and technology strengths already present. One was public administration; the other was education, opened to students in 1981.

It is important to note the features that make this undertaking unique. Although there are interdisciplinary educational science programs in many of the older Dutch universities, they are 2-year postsecondary courses for students, and they represent fairly traditional mixtures of psychology, education, and related social sciences; faculty research in these departments addresses important, but mostly traditional, educational problems. In Twente, the academic program in educational sciences and technology is designed expressly for students with strong preuniversity training in science and mathematics; it requires 4 years of study leading to the Dutch equivalent of a US master's degree. The aim is to educate students for careers in which the solving of complex problems within educational practice is central.

The essentials of behavioral and social science knowledge and methodology are included, but the major emphasis is on the use of this source to improve educational technology, especially the use of NIT in instruction. Instructional design and development, educational measurement, and evaluation are the foci. There is close cooperation with the Center for Educational Information Technology in the same building; this center is a national advisory body to public schools on the use of computers in education. There is also close cooperation with the Center for Educational Research and Development, an arm of the Twente University Science and Technology Departments, that specializes in instructional designs for the improvement of problem solving in science education at the university level (see previous article). There is also much interaction with government and industry as clients; students spend a significant part of their time working on instructional design and organization problems in various major electronics, manufacturing, banking, and retail sales firms, as well as several government agencies. The aim of this present work is to promote theory-practice and university-industry linkages. The course sequences are modularized, mastery-oriented, and largely self-paced. Detailed description of the educational program is provided by Plomp and Verhagen (1982, 1983).

Unlike most educational technology departments in the US, which have evolved in traditional colleges of education, the Twente program was established without precedents. Its view of educational problem solving is much more akin to the view of systematic analysis and scientific problem solving found in the physical sciences and engineering fields. Its approach and its goals, therefore, approximate more closely the ideal picture of a "design science" envisioned by Simon (1969) and Glaser (1977) than do most of the educational technology programs in the US. It will be important, as the Twente program continues to develop, to evaluate its impact on the major NIT-related problems in The Netherlands.

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*3/22/85*

# Biological Sciences

## BASEL INSTITUTE FOR IMMUNOLOGY, BASEL, SWITZERLAND

*by Claire E. Zomzely-Neurath. Dr. Zomzely-Neurath is the Liaison Scientist for Biochemistry, Neurosciences, and Molecular Biology in Europe and the Middle East for the Office of Naval Research's London Branch Office. She is on leave until July 1986 from her position as Director of Research, the Queen's Medical Center, Honolulu, Hawaii, and Professor of Biochemistry, University of Hawaii School of Medicine.*

The Basel Institute for Immunology (BII) conducts basic research with full academic freedom, even though it has been and still is supported entirely by F. Hoffmann-LaRoche AG, a family-owned Swiss pharmaceutical company. The work of this institute, like that of the Friedrich Miescher Institute (page 240), helps indicate the Swiss pharmaceutical industry's commitment to basic research.

### Background

BII was founded in 1968 and began operation in 1971 with Dr. Niels Jerne as the first director. Jerne shared the Nobel Prize in Medicine and Physiology with Drs. Milstein and Kohler for the concept and development of the methods for monoclonal antibody production. Dr. Fritz Melchers is the present director of the BII.

Most of the members of BII have temporary contracts for periods from 3 to 5 years, with only a few, including the director, having permanent positions. The members of the scientific staff, besides Swiss nationals, come from many continental European countries as well as the UK and the US.

The staff of the institute consists of three groups that are about equal in number: (1) scientists, (2) technicians, and (3) administrative, secretarial, and technical staff. Like the first two groups, the third also has considerable turnover. There is a board of directors which is responsible for the operation of BII and for ensuring its independence. BII also has a board of advisors which has an international representation. Most of the members of the board of advisors are former Nobel Prize winners, making this a very high-powered group.

In addition to the above-named boards, the institute also has a board of consultants. This board consists of scientists working in other laboratories in Switzerland. It acts in a capacity similar to the board of advisors, and, in addition, it encourages cooperation among immunologists in Switzerland.

### Research Projects

The number and diversity of research projects carried out at the Basel Institute of Immunology are so great that it is only possible in this article to list the general areas of research and to mention briefly some of the findings. About one-third of the projects have been cooperative work with scientists from Austria, Canada, Denmark, Finland, France, West Germany, Great Britain, The Netherlands, Sweden, Switzerland, and the US. The research projects encompass the following topics: gene structure; DNA cloning and transfection; structure and function of immunoglobulin; structure and synthesis of surface antigens; repertories of T and B cells; biochemical studies on activated lymphocytes; activation of lymphocytes by lectins and antibodies; lymphokines; hemopoietic factors; differentation *in vitro* and *in vivo*; cell surface of lymphocytes; formal genetics; lymphocyte migration; idiotypes; T cell lines and hybridomas; helper T-cells and T-B collaboration; autoimmunity; and development of new methods for immunological studies.

Research at BII has led to the development of new reagents and techniques. Monoclonal antibodies with interesting specificities have been generated. These include large libraries of gamma light chain-producing antibodies from mitogen-stimulated spleen cells of kappa light-chain-suppressed mice, and of antibodies from mitogen-stimulated as well as ovalalbumin-primed spleen cells in which rheumatoid autoantibodies could be found. Conditions for serum-free cultures of chicken lymphocytes were improved. Antibodies secreted by a B cell clone in semisolid agar can be detected, and single cells can be probed *in situ* for the expression of specific messenger RNA (mRNA), for example, B lymphocytes for the expression of Ig-specific mRNA. A

mouse fibroblast line has been established in culture that offers an alternative to L cells and NIH 3T3 fibroblasts for DNA transfection experiments. Methods for DNA transfection have been further refined. For the first time, a complete epitope-binding, biologically active Ig molecule was produced by gene-transfer techniques. With present methods for modifying genes, research is being carried out to construct new Ig genes, such as a variable region of heavy chains linked to a constant region of light chains. New alleles of genetic markers were found, and new halotypes and recombinants were bred. Two-dimensional gel electrophoresis is being used to analyze the phenotype of cells. A fully automated oligonucleotide synthesizer has been built at the institute's workshop. It uses the chemistry of oligonucleotide synthesis developed at the Roche Research Department to prepare probes for gene isolation and modification.

Conclusion

BII offers an ideal environment for a research scientist. Since the institute is entirely funded by the Hoffmann-LaRoche Company, the scientific staff does not have to apply to the Swiss government or to any other sources for research funds.

The main criterion for a research project is that it be innovative, without the requirement of any direct application to a potential product for Hoffmann-LaRoche. Thus, the independence of the scientific staff is equivalent to that at any university. Many of the scientists at the institute also teach at the University of Basel and train graduate students as well as post-doctoral fellows. Since most of the staff positions are on a temporary basis of 3 to 5 years--in some cases, 8 years--there is a continuing influx of new ideas and projects. In addition, the international composition of the staff is conducive to the generation of new concepts and to collaboration with scientists from other countries. The organization of the institute, in that there are no departments or sections and no chairmen, facilitates collaboration rather than competition among the scientific staff. They are also permitted to publish freely the results of their research. The excellence of the research has led to international recognition of the institute as an organization devoted to research of the highest quality.

*3/6/85*

## NEUROBIOLOGY AND GENETICS AT THE FRIEDRICH MIESCHER INSTITUTE, BASEL

*by Claire E. Zomzely-Neurath.*

The Friedrich Miescher Institute in Basel, Switzerland, is doing top-level research in neurobiology and genetics. This institute, like the Basel Institute of Immunology (page 239), is an example of the Swiss pharmaceutical industry's commitment to basic research.

Background

The institute was established in 1970 as an independent foundation by Ciba-Geigy Limited, a Swiss pharmaceutical company. The aims of the institute are: (1) to engage in basic research, originally in the fields of biochemistry and medicine and, more recently, in plant science; and (2) to provide an international center for research, study, and training for young scientists. This institute is entirely funded by Ciba-Geigy, but the staff scientists carry out research without constraints by Ciba-Geigy. Thus, this institute has the same independence in research projects as the Basel Institute of Immunology and the Roche Institute of Molecular Biology in the US, the latter two being entirely funded by the Hoffmann-LaRoche Company. The director of the Friedrich Miescher Institute is Dr. Edward Reich.

The institute was originally housed at the Biozentrum, University of Basel, but is now in new and larger quarters in the Rosental complex of Ciba-Geigy. These quarters are well equipped with supporting facilities required for modern research in the life sciences. Current work at the institute spans a wide range of subject matter in cell and molecular biology of eukaryotic organisms. The institute maintains a program of internal research seminars and journal clubs, seminars, and lectures by a constant stream of visitors from Europe and overseas, as well as meetings on special topics of interest. The staff scientists as well as research fellows comprise an international group representing, in addition to Swiss nationals, other European countries as well as Japan and the US. Some of the staff scientists as well as research fellows have temporary appointments for periods from 2 to 5 years, similar to the situation at the Basel Institute of Immunology. This turnover allows for an influx of new ideas and approaches to research projects.

A board of trustees is responsible for overseeing the long-term activities

of the institute. It is helped in its assessment of the institute's work by an independent scientific advisory board that consists of an international group of distinguished scientists: Edmond H. Fischer, University of Washington, Seattle, Washington; Walter Gehring, Biozentrum, University of Basel, Switzerland; Howard Green, Department of Physiology and Biophysics, Harvard Medical School, Boston, Massachusetts; Arthur B. Pardee, Sidney Farber Cancer Institute, Harvard Medical School, Boston, Massachusetts; Eric M. Shooter, Stanford University, Stanford, California; and Diter von Wettstein, Carlsberg Laboratory, Copenhagen, Denmark.

Research Projects

A large number of diverse research projects are carried out at the institute: gene expression in yeast; plant development; culture and genetic modification of cereal protoplasts; regulation of storage proteins in corn seeds; biochemical genetics of cultured plant cells; studies on cauliflower mosaic virus; gene expression in plants; neuronal microdifferentiation; desensitization of β-adrenergic receptors; glia-derived modulations of neurite outgrowth in neuronal cells; human oncogenes; human interferon; mechanisms of DNA repair; hormonal regulation of gene expression; regulation of tumor functions by hormones; structure, function, and hormonal regulation of specific eukaryotic genes; regulation of protein synthesis and S6 phosphorylation; molecular aspects of protein phosphorylation; structure and function of plasma proteases; hemopoietic cell differentiation and transformation; biochemistry of fibrinolysis; translational control mechanisms and clinical immunology; regulatory events of the cell cycle.

Since there are so many projects, only a few selected topics will be discussed briefly in this article.

Neurobiology

Neuronal Microdifferentiation. Synapse formation in the developing brain is an integral part of neuronal differentiation. As such it depends not only on the establishment of axon terminals and synaptic junctions but also on the extent and degree of branching of the axons and dendrites that provide the framework on which the synapses are made. All these elements are formed by a process in which morphologically and functionally distinct domains are progressively established within the neuroblast cytoplasm.

The research group headed by A. Matus is studying the molecular mechanisms which regulate this process of microdifferentiation in the developing brain. Much of their interest has focused on microtubule proteins because experiments with drugs that cause tubulin to depolymerize have shown that intact microtubules are essential for the growth of neuronal processes. Consequently, factors which influence microtubule assembly in the neuronal cytoplasm are also potential regulators of axonal and dendritic growth.

Matus and his collaborators have been particularly concerned with the group of minor microtubule-associated proteins (MAPs) because several of these have been shown to be effective promoters of tubulin polymerization *in vitro*. They are using both polyclonal and monoclonal antibodies to search for evidence that individual MAPs are associated with the growth of axons and dendrites in the developing brain and in brain cell cultures. They are also using antibodies to study synaptic junction proteins with the ultimate aim of establishing markers which can be used to investigate the regulation of synapse formation in the developing brain. As part of this approach, they are characterizing acidic amino acid binding sites in brain synaptic membranes which correlate with excitatory neurotransmitter receptors; the researchers intend to produce monoclonal antibodies against the receptor protein. They plan to use this combination of antibodies against axonal, dendritic, and synaptic junction proteins to determine what influences (hormonal and sensory) regulate the molecular mechanisms which underlie neuronal differentiation in the developing brain.

Glia-Derived Modulation of Neurite Outgrowth in Neuronal Cells. Neurite outgrowth is a phenomenon of crucial importance not only during the development of the nervous system but also during the phase of regeneration which can follow lesion of neuronal connections. Glial cells, including glioma cells, grown in tissue culture release macromolecular factors which promote neurite outgrowth, or survival of neuronal cells, or both. One of these factors induces neurite outgrowth in neuroblastoma cells. The institute's D. Monard found similar neurite-promoting activity in a medium conditioned by rat brain primary cultures. A correlation was found between the presence of biological activity in the medium and the age of the animal from which the primary culture was derived. This sharp rise in neurite-promoting activity released by brain primary cultures coincides with the period of rat brain development at which a burst of glial cell

multiplication takes place. Since neuronal branching strongly increases at, or immediately following, this phase, the results suggest that such glia-derived activity is relevant to brain maturation. The aim of the research group headed by Monard is to study the importance of this factor in brain development and in regeneration phenomena. To this end, these researchers have recently characterized the glia-derived neurite-promoting factor and have developed methods for its purification in reasonable amounts. This factor has been identified as a protein, and Monard et al. have developed *in-vitro* immunization techniques to produce monoclonal antibodies as tools for the identification of genes coding for the factor. They have also prepared the complementary DNA (cDNA) to the messenger RNA for the factor and are using the resulting double-stranded DNA to transform *E. coli* in order to amplify the cDNA and eventually isolate the genes for the factor. Using their dissociated cells from rat or mouse cerebellum culture under serum-free conditions, they found that their glial factor did inhibit certain kinds of proteolytic activity associated with the neuronal cells in the cultures.

Desensitization of β-Adrenergic Receptors. β-adrenergic receptors are linked to the membrane-bound enzyme adenylate cyclase. Thus, the properties of the receptor as well as their functional expression can be studied simultaneously. M. Staehelin and his group have been using various cell lines to study the functional coupling of the receptors; the researchers are trying to understand how cells regulate their response to hormonal stimulation.

## Genetic Studies

Gene Expression in Yeast. *Saccharomyces cerevisiae* (yeast) is one of the best understood eukaryotic organisms. The fact that this unicellular microorganism has a short generation time and is easy to grow under defined culture conditions has made it a favored object for biochemical and genetic studies for several decades. More recently, the newly elaborated yeast-gene cloning techniques have made it possible to extend the analysis to the molecular level. The aim of the research group directed by A. Hinnen is to combine classical and modern approaches in the study of gene expression in yeast. Their main emphasis is on the exploitation of DNA cloning, *in-vitro* genetics, and the reintroduction of genetic information into living cells to assay modified genes *in vivo*. In addition, they are developing yeast expression vectors and studying the parameters which control synthesis, stability, and secretion of yeast and nonyeast proteins. Hinnen et al. are using the acid phosphatase gene family as a model system to study gene organization and expression. Two of the structural genes, the regulated PH05 gene and the constitutively expressed PH03 gene, have been isolated and partly sequenced. The total DNA sequence of a 3.9 kilobase restriction fragment containing PH05 and PH03 in a tandem arrangement is now fully established. *In-vitro* analysis of the PH05 promoter has also been carried out, as have studies of the secretion of the PH05 gene product. The results showed that alterations in the signal sequence not only affect secretion but markedly change the glycosylation product. This group has also achieved expression of several foreign genes in yeast under the control of the PH05 promoter.

Gene Expression in Plants. In order to study plant gene expression and its regulation, the ideal scheme of experimentation includes: (1) the study of a gene of interest in a plant, (2) its isolation and characterization, (3) its *in-vitro* modification, (4) its reintroduction into a plant, and (5) examination of its expression in that plant. In some cases, rescue of the transforming gene is required. Several aspects of this scheme are being studied by B. Hohn and her group in collaboration with other groups both within and outside the institute. The genes under investigation are chloroplast genes, in particular those regulated by the nucleus, as well as genes of cauliflower mosaic virus. For the reintroduction of genes into plants, transformation with an engineered *Agrobacterium* Ti plasmid is being used in addition to a direct DNA-mediated transformation system. For the rescue of genes from transformed plant cells, these researchers tag the transforming DNA with the necessary λ sequence and isolate the desired genes by *in-vitro* packaging.

Hormonal Regulation of Gene Expression; Regulation of Tumor Functions by Hormones. E. Reich heads a large group studying plasminogen-activator (PA) genes. These are of interest from the standpoint of hormonal regulation because their expression can be modulated by a large number of hormones and hormone-like effectors such as tumor promoters, retinoids, prostaglandins, and several oncogenes. This group has cloned the respective cDNA and genomic sequences for some of the PAs from several mammalian species. The clones are being used for the identification and comparison of regulatory sequences

to obtain some insight into their evolutionary conservation or variability. The urokinase (UK) form of PA is being studied particularly in a cultured porcine kidney cell line in which the UK gene expression is responsive to physiological concentrations of calcitonin, vasopressin, hydorcortisone, and the tumor promoter phorbol myristate acetate. The PA form produced by HeLa cells is tPA. Reich et al. have used a cDNA clone of tPA to study the regulation of tPA expression in HeLa cells.

Reich's group is also studying the repression of gene expression by calcitonin. Their working hypothesis is that the cellular response to hormones in higher vertebrates involves changes in the activity of many genes, some of which are induced to higher levels of expression while others are repressed. Therefore, it follows that hormones influence cellular activities by modulating the expression of substantial genetic programs rather than of single genes. Such programs might include those responsible for determining the distinctive phenotypes of differentiated cells, and it is therefore of interest to try to identify the structural features that are common to different genes within a single hormonally regulated program. Because calcitonin induces UK production so strongly, experiments were undertaken some time ago to characterize the regulatory scope of this hormone in porcine kidney cells, and the results showed that at least 12 proteins were altered significantly after cultures were exposed to calcitonin. Molecular cloning was then undertaken specifically to isolate the cDNA (and, ultimately, genomic sequences) for proteins whose synthesis was repressed by calcitonin. Five repressed cDNA clones have been isolated and are being studied.

Another aspect of the research by Reich et al. is a study of the hormone response spectrum of tumors and the hormonal regulation of tumor growth. These investigators consider that studies of the hormonal regulation of PA production are of particular interest in the context of neoplasia for several reasons:

1. Because PA expression can be modulated by so many hormones, the response of individual tumors to some hormones could be assayed easily by monitoring changes in PA secretion of cultured explants. While enzyme production in any given cell type would not be expected to respond to all hormones, this assay would provide information about the spectrum of hormones influencing particular tumors that could not be easily obtained by other means.

2. It had been shown previously that PA production in tumors appears to be expressed as part of the growth program. That is, hormones which stimulate PA secretion in culture also promote tumor growth *in vivo*, whereas those which inhibit tumor growth repress enzyme synthesis in culture. Hence the patterns of PA response in tumor explants may identify hormones that regulate the growth of tumors *in vivo*, thereby providing an assay that could yield therapeutically useful data about individual patients.

3. Since PA production reflects cellular responses to modulating agents, changes in the rate of enzyme synthesis are a sensitive means of detecting and isolating new hormones. To this end, Reich et al. have exploited the utility of PA assays for defining new aspects of the endocrine regulation of rodent mammary tumors. The results obtained to date provide coherent support for the preceding rationale. Evidence has already been obtained for the existence of a hitherto undescribed hormone which has so far been purified over 2000-fold.

Human Oncogenes. Recent progress in several laboratories has demonstrated that various forms of human cancers contain alterations in a group of genes collectively termed oncogenes. These alterations (mutations, amplifications, and translocations) have been demonstrated and lead to a pathological activation of the particular gene in a given tumor. When the same genes become incorporated into a retroviral genome, spontaneously or experimentally, they cause the virus to become highly oncogenic, hence the term "oncogene." This lends strong credence to the concept that those oncogenes found to be specifically altered in a given human tumor also play a pathogenic role in that tumor. The proof of this concept and the elucidation of the mechanisms involved represent a challenging field in modern cancer research.

The research group directed by C. Moroni is studying the putative role of oncogenes in human leukemia. Their approach is to identify and clone activated genes directly from human patients, study the correlation between gene expression and the clinical source of the disease, and examine the function of cloned genes in experimental systems. These investigators have already obtained evidence of a significant association between oncogene activation and leukemia. They have also initiated a project to search for an "immortalizing" function in human leukemia. It has recently been shown that certain viral oncogenes

(myc, EIA, T) are unable to transform secondary rat-embryo fibroblasts but can provide an "immortalizing" function which together with a "transforming" gene can stably transform rat cells in nature. Such a function has not yet been demonstrated in human tumors. Reich et al., using the rat model, are searching for such functions, particularly in those leukemias where they have already identified an activated *transforming* oncogene. These researchers have also devised methods for the extrachromosal replication of plasmid DNA in thymoma cells as well as producing specific probes for the *oncogene from* human cell lines (N-*ras* gene) and have obtained monoclonal antibodies directed against peptides corresponding to the *ras* nucleotide sequence.

Human Interferon. H. Weideli and his group are engaged in studies of human interferon genes (IFN). These genes are good models for studying gene expression because their induction process is fairly rapid and the expression of their products is limited to a short period of time. This group has focused its research on two kinds of IFN: leukocyte IFN (IFN-α) and immune IFN (IFN-γ). IFN-α genes are expressed in most leukocytes and lymphocytes upon viral infection. Depending on the virus and the cell type to be infected, different IFN-α genes are expressed. In contrast, IFN-γ genes are expressed only in T-lymphocytes upon stimulation with plant lectins or unspecific antigens. T cells are therefore the cell type of choice since they are able to express both types of IFN, depending on the kind of inducer.

Several questions concerning the regulation of the different IFN genes have arisen, such as whether T cells have receptors whose activation leads to IFN-γ expression and which are absent from the surface of the other cell types. A second question is whether T cells are unique in having functional regulatory and/or structural gene sequences for IFN-γ. A third question is whether IFN-γ expression requires regulatory proteins different from those needed for IFN-α expression. Weideli et al. are emphasizing the third question in their research using cloned IFN-gene sequence as probes for the isolation of regulatory proteins. Because IFN-γ inducers, such as plant lectins, lead to the expression of a variety of lymphokines in T cells, they have focused their attention on B cell growth factor and T cell growth factor (TCGF). Both are induced within hours after lectin induction, and both seem to be regulated in a similar way to IFN-γ. Since both factors are important for the multiplication and maturation of lymphocytes, they may also play a crucial role in the *in-vivo* expression of IFN genes upon viral or antigen induction in these cells. Therefore, Weideli et al. are also studying these two lymphokines in order to compare the regulation of their genes with that of IFN genes. They have already produced monoclonal antibodies *against human lymphokines*, have carried out molecular cloning of the TCGF, and are carrying out studies on DNA binding proteins with specific affinity for IFN-genes. Their experimental approach should distinguish between common proteins and unique proteins on the basis of their binding to different DNA sequences involved in the regulation of IFN genes.

Conclusion

The Friedrich Miescher Institute is another example of the commitment of the Swiss pharmaceutical industries to the support of top-level basic research. This institute is entirely supported by funds from Ciba-Geigy Ltd., but has complete freedom in its research projects--similar to the Basel Institute of Immunology, which is funded entirely by the Hoffmann-LaRoche Co. The scientists can take advantage of new methods and expertise of the scientists in the research departments of Ciba-Geigy but have independence in their research projects. There is also interchange of information between scientists at the institute and those at the Biozentrum of the University of Basel and at the Basel Institute of Immunology. And there are some collaborative projects with scientists in the US as well as those in Swiss universities.

*3/8/85*

## BIOMECHANICS AND BIOMATERIALS TRAINING AND RESEARCH IN MARSEILLE

*by Thomas C. Rozzell. Dr. Rozzell is the Liaison Scientist for Biological Sciences in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on reassignment until August 1985 from the Office of Naval Research, Arlington, Virginia, where he is Program Manager for Bioelectromagnetics.*

The successful treatment of a wide range of traumatic injuries, such as are

encountered by military personnel, requires a close integration of surgery with a knowledge of the properties and characteristics of an ever-growing list of natural and synthetic materials. The Faculty of Medicine of the University of Aix-Marseille, France, has designed a teaching and research program aimed at providing orthopedic surgeons and others with a broad and comprehensive diploma built around biomechanics and biomaterials. This program could serve as a model for specialty training of military physicians who will be assigned to field hospitals or MASH units. I am not aware of a similar program in US medical schools.

The program, which trains 10 to 40 students per year, is led by Professor Agrege D. Poitout; it is the first of its kind in France, embracing the technological application of materials in medicine and cooperative work between hospitals, research laboratories, and industry. Poitout, himself a surgeon with impressive credentials, has organized this program, which each year trains professionals from all over France as well as other parts of Europe. The program has cooperative efforts with other countries within the European Community--Bern, Switzerland, and Brussels, Belgium, for instance.

Background

When the program began in 1982, biomedical technology was a F9 billion industry in France, spread over approximately 1000 individual companies. The world market has increased about 15 percent annually since, and the developed countries of the world have become increasingly aware of the economic potential of this sector of high technology. Even though France only occupies a minor position in this field, the secretary of state for technical and scientific research has designated it as one of high priority. France itself has only about 20 percent of its national market, with Japan, Switzerland, West Germany, and the US in the dominant position.

France currently implants annually a total of 50,000 hip prostheses; 5000 knee prostheses; 15,000 cardiac valves; 15,000 vascular prostheses; and 20,000 cardiac pacemakers. Many of the materials were actually developed for nonmedical uses in, for example, the aeronautics industry, the electronics industry, or agriculture. While the functional aspects of implanted materials can usually be predicted with a certain degree of accuracy, estimation of the biological performance still needs much research in order to be considered reliable in many cases. The progress which has been made in recent years in the study of the interface between materials and living tissues has enabled the development of implants which are far more reliable and effective. However, the biocompatibility of the materials used is still not completely satisfactory, and this would seem to justify an intensification of research and collaboration between designers (engineers) and users (clinicians).

Program Objectives

The course of study in Poitout's program is designed to be of interest to medical students (especially interns and assistants) who are preparing for orthopedic, cardiovascular, neurological, or general surgery; general anatomy; and dentistry. Some students who are in physical and biomedical sciences may also enter the course.

The training program is designed to enable future practitioners to become familiar with the technological and production problems of the prosthetic materials that they will be using. It is hoped that the program will help them discover perspectives for the future and areas for research.

Through close cooperation with manufacturers and researchers, the course aims to provide students with in-depth knowledge of new materials and new technologies to enable them to take their place at the forefront of current practice and to orient their research in terms of industrial needs. In a like manner, manufacturers will acquire a better understanding of practical problems, enabling them to solve them more satisfactorily and to provide materials that are better adapted to the needs of the clinician.

Program Organization and Options

The training program leads to the degree Diplome d'Étude Approfondie (DEA), an "in-depth diploma." It is the only such degree in the University of Marseille that is of interest to surgeons who are planning a university or research career. Students have several options available to them, according to their area of specialty; three study units must be completed to obtain the degree. Two of the units are required, the third is optional and is chosen specifically by the student. The study units are as follows:

- Unit 1: This is under the direction of physicians and chemists and deals with the problems of the composition, the structure, and the mechanical and electrochemical behavior of materials; of fixation in tissues; and of

the interface between these materials and biological tissue. Under this unit, the student must gain a thorough knowledge of the physical and chemical properties of the various biomaterials.

- Unit 2: This study unit is oriented toward biomechanics, histology, kinesiology, and the relationships between the various systems of tissue.
- Unit 3: Since this unit is optional, it covers a more specific application of the general principles in Units 1 and 2. It is through this unit that the instructors attempt to integrate the various surgical specialists, the physical scientists, and the dentists.

Students gain practical experience in laboratories of the various institutes and universities located in and around the Marseille and Aix-en-Provence.

The options are offered in an effort not to isolate the curriculum of the program in surgical specialties, but to offer training for students who wish to work in other research areas, such as data processing, genetic engineering, and biological engineering. Students who want to work in other areas are urged to take courses in other DEAs--such as biological and medical engineering, human paleontology, physiology, data processing, or statistics. As an example, one of the study units, entitled "The Biomechanics of Fossilized Man," may also be chosen by students and replace one of the study units, after prior arrangement with the responsible staff. Further flexibility is evident in the form of bridges between the DEA of biological and medical engineering and that of medico-surgical technology and biomaterials. Certain credits may be chosen from within one or the other of these two DEAs after prior agreement with the professor responsible for the course.

One example of a study/research outline will serve to illustrate more details of the program. Consider the program proposed for the DEA in medico-surgical technology and biomaterials, leading to the qualification in orthopedic biomechanics. It requires 112 hours of course work and 96 hours of practical work and directed study. The practical experience is gained within the university hospital's orthopedic surgery facilities, in the university science and medicine laboratories, and in other research centers in various towns outside Marseille. The three credit units of the program are:

1. Biomaterials: Physicochemical and Mechanical Aspects. Lecturer in charge: Professor J.P. Crousier of the St. Charles Faculty of Sciences, University of Aix-Marseille I. Other faculty professors, researchers from the National Scientific Research Center (CNRS), colleagues from industry, and other producers of materials also contribute to the teaching program of this unit.

2. Biomechanics of Tissue and Histophysiology. Lecturer in charge: Professor A. Bardot of the Faculty of Medicine, University of Aix-Marseille II. Histologists, physiologists, biomechanics, re-education specialists, and others also contribute to the teaching program.

3. Applications of Biomechanical Principles in Orthopedics. Lecturer in charge: Professor Poitout of the Faculty of Medicine, University of Aix-Marseille II. Designers and producers of orthopedic material also contribute their experience in this specialized field.

If this third credit is taken by someone in the Faculty of Odontology (Dentistry), the qualification will be in biotechnology and biomaterials in odontology.

The three units of study are coordinated by Poitout, who has overall responsibility for this DEA.

Entry Requirements

Several certificates and courses may be considered as valid entries to the DEA, and must be approved during the year preceding entry into the program by the lecturer in charge.

In order to integrate surgical experimentation into their program, one of the professors has suggested that the course surgical methodology constitute a valid entry to the DEA program, as well as the microsurgery seminar. Another route into the program is via the practical examination in Initiation into the Surgery of Leprosy, which is in the Pharo Military School for the training of future military doctors.

Facilities and Locations

While the program is focused around the University of Aix-Marseille, the formal instruction is drawn from a number of other universities, research institutes, hospitals, and medical schools. Classroom instruction is provided by three faculties of the University of Aix-Marseille: Faculté de Médecin et d'Odontologie, Faculté des Sciences Saint Charles, and Faculté des Sciences Saint Jerome. In the nearby region of Marseille, there are four research laboratories that are associated with the program and into which students may go for thesis work (independent research) and hands-on training.

These are the laboratories of the Centre National de la Recherche Scientifique of Marseille, of Société Nationale Industrielle Aérospatiale of Marignane, of the Center for Atomic Research of Cadarache, and several industrial research laboratories. Outside Marseille and its immediate vicinity are other affiliated institutions: the faculty of Medicine at the University of Lyon, at Toulouse, at Montpellier, at the military hospital of Toulon, and at the University of Nice.

*3/19/85*

## BONE REPLACEMENT AND DRUG DELIVERY AT THE FREE UNIVERSITY OF AMSTERDAM

*by Thomas C. Rozzell.*

Traumatic injury caused by projectiles or by a number of routine activities of military personnel must often be treated by replacement of bone tissue. Over the years, surgeons have used a number of synthetic materials in addition to autologous, homologous, or heterologous bone. Materials that have been used for such biomaterials include metals, alloys, glasses, ceramics, carbons, polymers, and a host of composites of these and other substances. The search for an ideal bone-substitute material is one of the primary activities of the Biomaterials Department in the School of Dentistry at the Free University of Amsterdam. This group, led by Professor Dr. K. de Groot, is also involved in research on the controlled release of drugs using polyphosphazenes. They have made recent progress in their research on calcium phosphate ceramics and have opened up new drug delivery approaches with polyphosphazene polymers.

### Bone Material Studies

Biomaterials are probably used more in dentistry and orthopedics than in other medical professions. In addition, both professions work almost exclusively with hard tissue. Biomaterials are used to restore the normal function of bone; for repair, replacement, or augmentation of deficient tissue; and for the support of prostheses. To be considered successful as a biomaterial, a substance must meet several very exacting conditions. In particular, it must have certain mechanical and biological properties, it must have the capability of being fabricated into functional shapes, and it must not be toxic. When one places a biomaterial in a living tissue environment, an artificial interface is created between the living tissue and the biomaterial. Ideally, the interface between the implant and the surrounding tissue should behave similarly to a normal biological surface present at the same place in the healthy tissue. The ultimate goal of implantation of biomaterials in the skeleton is to reach full integration of the nonliving implant with the living tissue. The extent to which the bone-implant combination will be able to function as an integrated mechanical unit depends largely on the mechanical and physiological characteristics of the living bone, the chemical and physical properties of the implant, and the interaction between the bone and the implant.

Bone is a mineralized connective tissue, the main constituent of which is a conglomerate of calcium salts; its composition is still not fully understood. Approximately 60 percent of the mineral bone is crystallized calcium hydroxylapatite. The organic component is primarily collagen. The physical properties of bone result from a combination of the collagen's tensile strength and the compressive strength of the calcium hydroxylapatite and the other calcium salts. It is thought that the collagen and hydroxylapatite are bound together very tightly and that this is what gives the bone matrix its unique mechanical properties. Bone, being living tissue, is porous to allow penetration of nutrient material into its vascular system. Thus, any material that is to be used as a bone substitute must have a specialized architecture and some rather distinct properties.

De Groot's group has turned its attention to calcium phosphate ceramics in an effort to find a suitable material to replace or augment bone in several parts of the skeleton. In some instances they are interested in a material that will maintain its integrity indefinitely in the body, and in others they want a material that will slowly degrade as it is replaced by natural tissue. One characteristic of ceramics with calcium phosphate surfaces is their ability to form a tight bond with bony tissue. They are, therefore, called bioactive bioceramics, in contrast to other ceramics that do not have this property.

Another important feature of calcium phosphate ceramics is their porosity. Depending on the technique used for sintering (fusing), one can create pores with a diameter greater than 100 μ that will allow bone ingrowth, or pores of only a few microns that do not allow such ingrowth. The larger pore size also effectively enhances the available

surface for cellular interaction with surrounding tissue. Finally, the tensile and compressive strength of these ceramics is very close to that of natural bone, so there is not a large mismatch in strength when they are combined with bone. Two methods have been suggested by de Groot and his coworkers to prevent fatigue failures in ceramics. The first is reinforcement with metallic structures of high fatigue resistance to stop small cracks from growing into large ones. The second is prestressing--that is, keeping the ceramic device under a permanent compression, thus preventing small cracks from forming and existing small cracks from growing. Both of these methods require that other materials be added to the bioceramic, giving composite structures.

Perhaps the most important feature of these bioceramics is their excellent biocompatibility, not only with bony tissue but with epithelial and connective tissue as well. When these materials are implanted in bone, a tight bond results. It isn't even necessary to have an exact fit between the implant and the bone, for new bone grows within a few weeks to fill the spaces. In fact, Denissen and de Groot (1979) showed that the bond that develops between bone and these ceramics is usually so strong that the implant cannot be removed without fracturing surrounding bone. The group has done studies in which these ceramics were used in rats, rabbits, dogs, and guinea pigs; in such sites of implantation as the alveolar bone (for dental purposes), vertebrae, long bones, and the skull; and for replacement of auditory ossicles (de Groot, 1981). All their studies have shown conclusively that calcium phosphate ceramics are not rejected by the host, but are integrated into the bony tissues at the implant site.

In terms of biocompatibility, they have found that there is no difference between very dense material and that having pores large enough for bone ingrowth. C.P.A.T. Klein, a veterinarian who has recently taken a PhD under de Groot and has remained in the department, has found some slight differences in the number of macrophages around the surfaces of implants of different types of calcium bioceramics.

Normal bone is continuously replaced (remodeled) in living subjects. Old bone is degraded and replaced by new cells. This process is not fully understood yet. It seems reasonable to assume that calcium phosphate ceramics undergo a similar degradation when implanted. Klein studied this phenomenon extensively using rabbits. She placed cylinders of the ceramics in the tibiae and evaluated the extent of biodegradation by radiography, light and fluorescent microscopy, microradiography, and porosity measurements. She found that three factors dominate biodegradability: crystallography, stoichiometry, and the degree of porosity. However, the literature does not show agreement on these or any other factors.

Klein also found that immune system mechanisms may influence biodegradation as does the ultrastructural geometry of the sintered particles making up the ceramics. In terms of the immune process, she noticed that certain ceramics act differently with respect to immunologically important serum proteins. It is possible that phagocytosis is affected.

Finally, Klein looked at the biodegradation behavior of calcium phosphate materials in subcutaneous tissue by implanting disks under the skin of rabbits. Here again, the bioceramics were noninflammatory and nonosteogenic. They were completely biocompatible. The extent of biodegradation was determined by light microscopy and macroporosity measurements. She concluded that the biodegradation behavior of calcium phosphate materials in subcutaneous tissue differs from that in bone. In the soft tissue it seems to occur primarily by dissolution and phagocytosis.

## Drug Release Studies

The major focus of drug-related research over the years has been on the development of potent drugs with new types of biological activity. Though this type of research continues, increasing attention is being devoted to the manner in which these drugs are administered. This has given new impetus to research into controlled release, making it a rapidly expanding area in biomaterials (see *ESN* 38-10:526-530 [1984] and 39-5:187-190 [1985]). Much of the research has centered around various classes of polymers. Recently a new class of polymers with an inorganic backbone has emerged as a candidate material for application as a drug deliverer. These materials (polyphosphazenes) seem to be able to act either as carriers of drugs, as bioerodible implantable material for prosthesis, or both.

The use of a bioerodible polyphosphazene as a temporary substitute for hard tissue seems extremely attractive since degradation of the backbone produces phosphate and ammonium ions which, at physiological concentrations, are harmless. Several other features of this class of compounds have compelled de Groot's group to study them:

1. The compounds are synthesized through a unique process that allows the polymer to be made with special characteristics for specific applications.
2. Preliminary tests of some of the nonbioerodible polyphosphazenes--i.e., those that are stable in a biological environment--indicate that they have good biocompatibility.
3. The synthesis of the polymer does not require initiators, stabilizers, or plasticizers which often cause toxicity problems with polymeric biomaterials.

The first project involving polyphosphazenes has been an attempt to develop a bioerodible carrier system of agents that influence bone formation and resorption. This type of device would act as a prosthesis and disappear as the formation of new bone occurs. Ideally, the degradation should proceed at the same rate as new bone is formed. In addition, it was thought feasible to incorporate a bone-active material that is released as the polymer degrades. This bone-active material could either be a substance that stimulates bone formation or retards bone resorption. To ensure controlled release of the active compound upon polymer degradation, it was proposed to link it directly to the polymer chain.

To study the feasibility of this concept, C.W. Grolleman developed an erodible "pendant" system; this is a system in which the drug is chemically bound to the polymer. Actually two methods of attaching the drug to the polymer were tried. In one case the drug was bound directly to the polymer, and in the other it was held by a spacer. In either case, the drug was released uniformly as the polymeric matrix degraded. The use of a spacer has at least two advantages if it works:

1. It expands the scope of the concept by providing alternate means whereby the drug can be attached to the polymer. There may not always be a functional group within the drug molecule suitable for reaction with the polymer chain.
2. It gives a maximum degree of substitution by reducing the possible steric hindrance of bulky drug molecules.

The release rate can be varied by changing the nature of the phosphorus-spacer bond.

Grolleman chose naproxen [(+)-2-(6-methoxy-2-naphthyl) propionic acid] as the model drug. This molecule is a relatively simple one since it has only one reactive functional group. Naproxen and its main metabolite (desmethyl naproxen) can easily be detected and quantified by ultraviolet or fluorescence spectroscopy. They can be separated from plasma or urine to obtain pharmacokinetic profiles of the drug.

The first part of Grolleman's studies focused on the synthesis and characterization of a copolymer containing naproxen linked to the polymer chain via a spacer, lysine ethyl ester. He did not attempt to achieve release of naproxen to an extent that a therapeutic level could be reached since this was not the purpose of this early phase of the research. He was mainly trying to prove the applicability of the concept of using polyphosphazenes as bioerodible drug carriers. Polyphosphazenes of different molecular weight as well as polymers having a different substitution were synthesized and characterized by spectroscopic methods and gel permeation chromatography.

The *in-vitro* release experiments and their mathematical description formed the second part of Grolleman's study. A zero-order release rate was found when pellets of the prepared polymer were put into buffer (pH=7.4) at 37°C. The observed release rate depended upon the degree of substitution as well as the molecular weight of the polymers he prepared. The drug was totally released at 60°C. Upon release, the polymer matrix gradually disappeared.

The third part of this study was a series of *in-vivo* experiments to test the efficacy and feasibility in animals. A pellet of the naproxen-containing polymer was implanted subcutaneously in rats. Histological examination of the implant site showed that a thin capsule was formed around the polymeric device, but no signs of an inflammation reaction were observed. Thus, the conclusion was drawn that the implant was well accepted by the body tissue involved.

## Conclusion

The group at Free University is moving in a number of directions and is anticipating work in still other areas. This appears to be a very active and innovative group that will certainly be heard from in the biomaterials research area.

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*3/21/85*

# Computer Sciences

## FORCEFUL CRUSADERS FOR DECLARATIVE SYSTEMS AND LOGIC PROGRAMMING AT IMPERIAL COLLEGE

*by P. Roman. Dr. Roman is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on assignment until September 1987.*

The Imperial College of Science and Technology in the museum district of London's South Kensington area was established by a 1907 Royal Charter "to give the highest specialized instruction, and to provide the fullest equipment for the most advanced training and research in various branches of science, especially in its application to industry." These precepts are fulfilled to an admirable degree by the internationally famed Declarative Systems Research Group within the Department of Computing. The group consists of the Logic Programming subgroup, led by Professor R. Kowalski and Dr. K. Clark, and the Functional Programming and Computer Architecture subgroup, under the leadership of Professor J. Darlington. Aside from substantial in-house financing, the group also enjoys external support from the UK's Science and Engineering Research Council (SERC), the Alvey Directorate, the European Economic Community's ESPRIT research program in information technology, and industrial sources. It is going to cooperate in a consortium with Plessey and Manchester University, and it has numerous international connections.

It appears to me that even though technical reports on specific (often spectacular) results of the group and technical details (about machines or configurations) have been publicized in various media, the general philosophy of the group's work is not well known and not properly appreciated in the US. This article first examines that philosophy and then discusses research in a not-yet-distributed "3-year plan" of new projects that will benefit from the forthcoming influx of ESPRIT support.

### Basic Philosophy

Conventional high-level languages (like Fortran or Pascal) are made up of commands which specify the actions to be performed. They can be characterized as procedural or imperative languages. But conventional software development involves requirement analysis, system specification, design, and implementation; and only the last is computer executable by procedural languages. Even though modern abstract methods using such languages may be employed to achieve a rational and comprehensive software development (*ESN* 39-5:190-192 [1985]), a more general and probably more soundly based approach is the one rendered by fifth-generation declarative systems based on logic languages, or functional languages, or both. These languages are primarily descriptive (as opposed to procedural), and they furnish definitions of a set of relations (PROLOG) or functions (LISP) to be computed.

In the late 1960s, it was recognized that much could be done with a declarative language, but progress was held up because, as the group at Imperial College sees it, there was not enough attention given to deductive reasoning. Instead, the American artificial-intelligence community committed itself to the use of LISP-based systems, still employing procedural emphasis. The dominant approach evolved as a "production rules" methodology. Meanwhile, the Marseille scientists, with Colmerauer's leadership and assisted by other European groups, developed the PROLOG (Programming in Logic) language, based on first-order predicate logic and theorem-proving capabilities. It has a pattern-goals modular structure which results in clear, accurate, rapid programming. Kowalski feels that there is only one intelligent way to process information--namely by applying deductive inference methods. But he also emphasizes that the *language* PROLOG must not be confused with the *concept* of logic programming. PROLOG is *based* upon logic programming, and the latter implies contributions to program specification, data description, and query and knowledge representation in general. Logic programming, of which Kowalski is perhaps the most prominent proponent, respects the semantics of logical implication: any answer to a query is simply an abbreviation for a sentence which is a logical consequence of the program. Hence, logic programs can be understood declaratively without reference to the behavior or working of the computer. From this, it follows that declarative systems (whether based on logic or functional languages) unify

various formalisms used for software development. Actually, they are frameworks for knowledge representation, and they separate knowledge representation from problem solving.

It is interesting to note, says Kowalski, that there are simple mathematical relationships between functional languages and logic languages. As is well known, a function can be regarded as a special case of a relation. On the other hand, relations are nothing but Boolean valued functions. In a sense, this observation implies that functional programs are more like conventional, imperative programs because they compute a single output, given a single input. But logic programs compute several alternative outputs for a single input. Thus, functional programming languages can be implemented more efficiently and can well accommodate sophisticated type structures. A major part of the Imperial College research plan is the integration of the different features and concomitant merits of functional and logic programming languages, while at the same time continuing their further development within their own paradigms.

One more fundamental observation made by Kowalski is this. Declarative languages, as noted earlier, separate knowledge of a problem domain from the way that knowledge is used to solve problems. The consequence is that sequential execution can be automatically replaced by parallel execution without changing the declarative meaning of the knowledge which is used. This observation led to the recent development of the PARLOG language (see below) and no doubt was also one of the strong reasons for the Japanese fifth-generation project to adopt logic programming (and PROLOG) as a basic ingredient.

In the coming years, the Declarative Systems Research Group intends to concentrate on developing general tools and techniques rather than on perfecting specific applications.

Overview of Research

The following is a summary of some of the planned research.

1. User Interface. Use of PROLOG and expert-system techniques to provide an intelligent front-end to an existing statistical package. Natural language interfaces. Window-based interface to sigma-PROLOG on the Macintosh computers.

2. Knowledge Representation and Problem Solving. Development of the use of logic as a knowledge representation and problem-solving paradigm in its own right, and investigation of the use of logic for rational reconstruction of other paradigms. Examples: automated theorem-proving, meta-level reasoning, knowledge assimilation, default reasoning; rational reconstruction of frames and production rules. Unification of logic programming and functional programming. Extension of logic programming to include additional features of classical and possibly nonclassical logic. (This implies going beyond the customary Horn clause logic and incorporating negation by failure, rules as conditions of rules, lists of solutions as individuals, elimination of rules, hypothetical reasoning, etc.)

3. Declarative Programming Environments. Declarative language system for executing user-friendly syntatic forms; using transformation techniques to convert such forms into efficient programs. Declarative programming tools for use within a parallel or distributed system.

4. Declarative Language Development. Unification of logic and functional languages. Type checking mechanisms in logic programming. Higher order functions. Relation between object-oriented programming and logic programming.

5. Miscellaneous Applications. Incorporation of heuristics with the use of causal models. Comparison of rule-based approaches to the construction of expert systems with other approaches (frames, production rules). Relationship between declarative systems and fourth generation systems/methodologies. Relational databases as special cases of logic databases. Representation of events and time, database update. Logic databases regarded as knowledge bases; assimilating incomplete and inconsistent knowledge. Knowledge representation and problem solving. Use of the Kowalski-Sergot calculus of events for dealing with database-update needs and plan formation. Development of previous work on knowledge assimilation needs within the frame of real-life applications; restoring consistency when a contradiction is encountered.

The sixth and seventh areas will include Computational Models and Computer Architectures.

Extension of PROLOG

As mentioned earlier, Drs. K. Clark and S. Gregory have developed a new extension of the PROLOG language. The extension is aimed at using the capabilities of fifth-generation machine architectures for parallel computing. This brief discussion captures some of the flavor of current work and may be of interest to some readers.

The PROLOG language and its customary versions/realizations are strictly sequential. PROLOG executes both procedures and procedure calls one at a time

in the order in which they are written. When a procedure call succeeds, PROLOG advances to try the next procedure call, and when a procedure fails, it backtracks to try again the most recently executed call which has an untried responding procedure. But this is not an inherent feature of logic programming. Indeed, logic programming provides opportunities for at least two kinds of parallelism. One is called "and-parallelism." This is possible if several subproblems can be pursued simultaneously--i.e., if we have a B& C&...&D structure. The other kind is the "or-parallelism," which is possible when several alternative rules, like:

A if (B&...&C),
A if (D&...&E)

can be used to solve the same problem at the same time.

Now Clark and Gregory have designed a new language called PARLOG (short for Parallel Programming in Logic), which is a logic programming language in the sense that nearly every procedure, definition, and query can be read as a sentence in predicate logic. It differs from PROLOG precisely in the incorporation of parallel modes of evaluation. It distinguishes and separates and-parallel and or-parallel evaluation. Relations are of two types: single-solution relations and all-solution relations. A conjunction of single-solution relation calls can be evaluated in parallel with shared variables acting as communication channels. Only one solution to each call is computed. On the other hand, a conjunction of all-solution relation calls is evaluated without communication of partial bindings, but all the solutions may be found by an or-parallel exploration of the different evaluation paths. The interface between single-solution and all-solution relations is provided by a set constructor.

Conclusion

The Imperial College research group promises to stay in the forefront of revolutionary developments in intelligent systems and related areas, and perhaps deserves more attention from across the Atlantic.

*12/14/84*

## SUPERCOMPUTER ARCHITECTURE AT SOUTHAMPTON UNIVERSITY

*by J.F. Blackburn. Dr. Blackburn is the London representative of the Commerce Department for industrial assessment in computer science and telecommunications.*

Researchers at the UK's Southampton University are planning to build a supercomputer using the Transputer manufactured by INMOS Ltd. of Bristol as a principal element. The work is being sponsored by the Alvey program, the UK's 5-year research effort in computer science.

The name "Transputer" has been given to a chip which combines a processor, memory, and communications links in the same chip; the name originated with INMOS, which manufactures Transputers with 16-bit and 32-bit words. The memory size will normally be 4000 8-bit bytes.

The Southampton University system is being designed for scientific computing where very high speed is essential. Dr. Christopher Jesshope, the team leader, stresses the flexibility of the architecture, which will make the machine useful in many areas of science and engineering. The basis for the flexibility of the system is its dynamic reconfigurability, which Jesshope calls adaptive parallelism. Applications involving regular meshes or matrices can be mapped onto an array architecture like the International Computers Limited (ICL) Distributed Array Processor (DAP). However, problems arise in mapping an application with fixed dimension onto the fixed parallelism of the array architecture (64×64 array of processing elements in the ICL DAP).

The RPA

Southampton University is developing a switch system for routing information between Transputers. This is a central concept in the Reconfigurable Processor Array (RPA). The RPA can adjust itself with considerable flexibility to the structure of almost any problem.

The original mechanism for reconfiguring an array of single-bit processing elements uses a single bit of reconfiguration control stored in each processing element. This bit controls the source of the carry in arithmetic operations, so that a number of bits may be linked together to form a multibit processing element. Using parallelism from the array to perform operations in a bit-parallel manner has the effect of reducing the overall word parallelism required from a particular application program. This scheme, however, can only adapt in one dimension of the array.

The RPA is flexible enough to adapt in any dimension. The 1-bit cells have been designed as bit slices, which can

be configured to form very powerful processing elements of virtually any size. If the bits in memory are thought of as a two-dimensional array, with the bits of the kth word forming the kth horizontal row, then the 1th bit slice is the bit sequence formed from the 1th bit of each number or the 1th vertical column of the array. Any connected path of bit slices may be configured into a powerful and flexible processing element. The success of this design is due to the distribution of a larger part of the control word to the processing element, so that it may be preset using local data to control the configuration of the array. Figure 1 illustrates the concept of the distribution of a portion of the control word to obtain adaptive behavior. Figure 2 gives the estimated performance for the RPA doing 16-bit integer addition. The dashed lines in the figure indicate performance degradation that would be found in a nonadaptive array.

Because of pending patent applications, Jesshope did not give me a detailed description of the architecture of the RPA. In general, however, the RPA cell consists of three main components: the switch, an arithmetic and logical unit, and memory. The architecture uses a symmetrical four-bus structure, which enables two arbitrary functions of the two source buses to be placed on the output buses in every read-modify-write operation. This structure is also maintained through the nearest neighbor switch, giving twice the bandwidth (for a given cycle time) found in other architectures of this type. For arithmetic

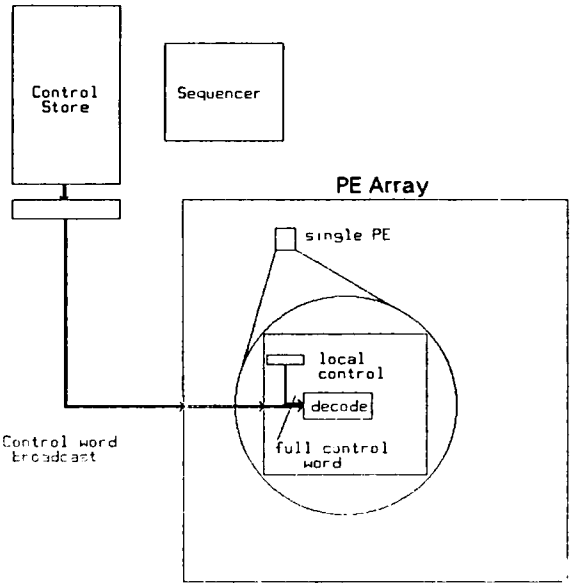



Figure 1. Distribution of control to the processing element (PE) array.

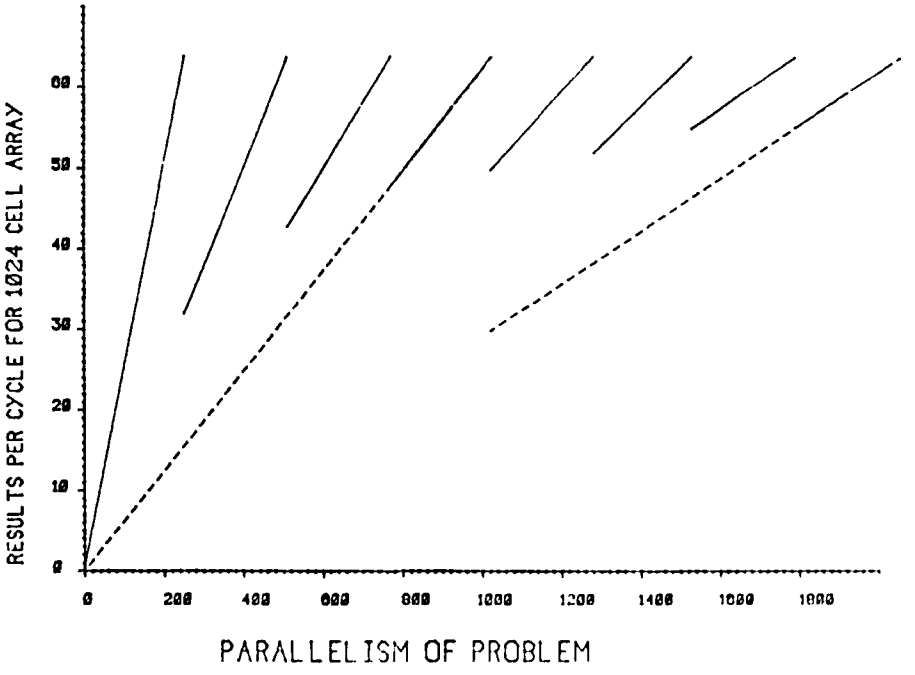



Figure 2. Projected performance of RPA for 18-bit integer addition, in results per cycle for a 1024-PE array.

operations the two functional units can be programmed to control the carry-propagation unit. This uses signals to indicate whether the two operands propagate a carry, generate a carry, or kill a carry.

The dual-result bus structure is useful for fast arithmetic and for communication, and it reduces the overhead involved in setting up the control logic to reconfigure the cell. The arithmetic and logical unit is highly flexible and has a fully coded structure. Ten control bits are used, with four bits each to the functional units and two bits to determine the mode of operation (arithmetic or logical, ripple or carry-save addition).

The RPA memory is essentially serial, with a programmable word length. It contains logic to accelerate floating point performance. Its performance should be four to 20 times that of the ICL DAP architecture for an array of a given size and cycle time.

The architecture of the RPA is being implemented in the 2.5-μ complementary metallic-oxide semiconductor (CMOS) process of General Electric Company (GEC, UK). Research is under way to implement a complete system on a wafer. In order to minimize and equalize communications delays between cells, an isomorphic silicon implementation is planned. In the two-dimensional floor plan adopted, data communication is optimized at the expense of duplicating the control bus. For this reason, the width of the control bus has been minimized in the design.

For speed and compactness, N-MOS switch arrays have been used extensively in the design of the arithmetic logical unit and the switch. Storage in the process element is provided by trickle-feedback latches, and the extensive local decoding used for the memory and further array configuration is provided by a complementary gate-matrix layout. A system which takes schematic diagram input and provides the gate matrix layout, has been implemented in Pascal.

The RPA cell architecture is fully specified and is now being implemented as a CMOS chip. Layout has proceeded to the cell level only, and a prototype single process-element circuit will be fabricated at Southampton prior to committing a full chip to the GEC process. The full chip should be fabricated during the third quarter of 1985 and will contain 16 process elements and a little more than 1K bits of memory. Work on a wafer-scale integrated implementation is at an early stage.

## The Transputer

The Transputer, expected to be available from INMOS later in 1985, has both physical and logical features to support parallel processing. It has four dedicated input/output links which enable it to communicate with other Transputers. The programmer can use the Occam language to create processes which run in parallel and exchange messages. Another project using the Transputer as a building block is under way at Imperial College, London (*ESN* 37-10/11:400-403 [1983]). However, the Imperial College computer, called a graph reduction machine, is being designed for intelligent knowledge-based usage.

The Alvey contract with Southampton University calls for developing a supernode containing a number of Transputers. The number of Transputers per node will be variable but will be around 25. The supernode will in turn be a building block for very large, powerful machines. Jesshope's objective is to build a 64-node system with about 1000 Transputers. Such a machine would have the raw performance of about 1 billion floating point operations per second.

Data between the Transputers within each supernode will be routed through the Southampton-designed switch chips described above. These semicustom chips will use the Science and Engineering Research Council's UK5000 gate array design.

The switch settings will be programmed at the beginning of each computation and left alone for that particular computation. The RPA will perform best in highly repetitive computations where the data flows can be planned and optimized in advance.

In the RPA the need for communication between supernodes is reduced by assigning a large segment of a problem to each supernode. The larger the segments, the less communication required. Even though the Transputer is well equipped to communicate with other chips, it runs fastest when most of the data and instructions it needs are located in its own 4-kilobyte memory. Within the supernode, each Transputer will be assigned to a separate task. Some will work on the computations required by the problem and some will take care of "housekeeping."

Tasks will be distributed among the supernode's Transputers so as to exploit the parallelism of the algorithm. For example, in operations on two-dimensional arrays (matrices) it may be possible to carry out the same operation on every element of the matrix concurrently. The data should flow smoothly through the

supernode, arriving where and when they are needed.

The programmer will determine the exact pattern of the flow. The plan is to compile Occam code into switch settings.

Conclusion

The Southampton University project is ambitious, and it is highly dependent on the success of several factors. The Transputer, which is the main building block, has yet to be delivered, although test versions are in operation at INMOS. However, Southampton needs a 32-bit floating-point version of the Transputer; the Transputers currently being tested are fixed-point 16-bit and 32-bit chips, each with 4000 8-bit bytes of memory. Also, the Southampton-designed RPA has yet to be built and tested, although its architecture has been fully specified. The expected performance of a 1000-Transputer system is, of course, yet to be determined. The objective is 1 billion floating point instructions per second. If this is achieved, the computer will be highly competitive with recently announced machines in the US and Japan. This is especially true since Jesshope expects the price of such an RPA supercomputer to be substantially lower than those of such recently announced machines.

*3/4/85*

# Material Sciences

## THE WELDING INSTITUTE, UK

*by Kenneth D. Challenger. Dr. Challenger is the Liaison Scientist for Materials Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on leave until May 1986 from the Naval Postgraduate School, where he is Associate Professor of Materials Science.*

The Welding Institute is probably the best institute of its kind in the free world. Located at Abington (near Cambridge), UK, it serves as the center for professional qualification, practical training and education, research, and support to the UK industries involved in fusion welding and other joining techniques. It is supported by membership fees from participating government agencies and industrial firms worldwide; thus its research is focused on current and near-term problems, but some research of a basic nature is carried out.

The US Navy was a member until the beginning of this year. In the past few months the Welding Institute (WI) arranged to have all of its 110 American members transferred to the newly organized Edison Welding Institute in Columbus, Ohio. (After months of planning, the WI's North American office, Ohio State's Center for Welding Research, and the Edison Welding Institute merged to form the new Edison Welding Institute.) However, all of the WI's past American members continue to have unrestricted access to the Abington facility.

The research at the WI is of high quality and in many instances focuses on problems which are germane to the US Navy. The manner in which the WI obtains financial support for research is somewhat unusual, and since it has proven to be very successful, I will review the financial structure of WI as well as a few of its more relevant research programs.

Finance

The total income for the 1983 fiscal year was slightly greater than £10 million. Of this, about £500,000 were reinvested in the facilities. This represented about a 10-percent increase in income over 1982 and a doubling of the amount of surplus that was reinvested.

The institute is organized into three divisions: Research (£8.3 million income), Professional (£0.14 million), and Communications and Training (£2.0 million). Of the total income, about 30 percent is from outside the UK, of which about £1 million was from the US. About 80 percent of the institute's income is from industrial members; the remaining 20 percent is from the UK Department of Trade and Industry.

The income from the Research Division is by far the largest. About £2.6 million is from membership fees (only one-third of this is from the UK). This funding supports what is called the core research program, which is planned by the staff at the institute and approved by the Corporate Research Board, a committee elected from member companies. In general these research funds are used to perform the more fundamental research and to address the long-term problems of industry. The other sources of funding for research are from group-sponsored projects (usually conceived by

the institute and then "sold" to some of the member companies) and single-sponsored projects. The results of these group and single-sponsored projects are only available to those specific sponsors, whereas the results from the core program are available to all members.

The Professional Division has actually been "in the red" for several years now; in 1983 the income of £140,000 resulted in a loss of about £19,000. There has been a steady decline in professional membership which has probably been caused by the reduction in the labor force in the British manufacturing industries. The income for this division comes from the membership fees of chartered engineers, technician engineers, and technicians.

The Communications and Training Division's income comes from conferences, seminars, publications, films, and information services. The total income from these activities is about £2 million, which resulted in a surplus of £145,000 (up from £89,000 in 1982). The WI operates schools of welding technology, applied nondestructive testing, and full certification schemes for weldment-inspection personnel. These courses are held all over the world; the major certification exams for weldment-inspection personnel are held at the institute, at Paisley College of Technology (Scotland), and in Singapore. Approximately 85 candidates per week are involved in this certification program. The WI has a cooperative arrangement with the Cranfield Institute of Technology for a modular diploma course in welding engineering (essentially a master of science program).

From the brief discussion above it is clear that the WI serves all phases of the manufacturing industries that use welding and does so at an international level. By far the largest division is the Research Division. The details of the activities of this division are discussed below.

Research Division

The Research Division employs about 420 people and is divided into seven departments: Materials; Engineering; Structures and Computing; Arc Welding; Control Engineering Support; Advanced Heavy Products; and Sheet and Precision Processes. Hundreds of research programs are active; however, many of these are either group or single-sponsor projects, and thus the results are only available to the sponsors.

Arc Welding Department

The majority of the research in this department is focused on developments in automation and improved welding productivity. (Note: in general, there is much less effort on automation and welding processes which lend themselves to automation--i.e., gas tungsten, gas metal, and submerged arc welding [GTAW, GMAW, and SAW]--in the UK than in the US. This, I believe, is due to the strength of the unions in the UK.)

Mechanized pulsed GMAW and semiautomatic GMAW spot welding processes have been developed for thin aluminum sheet. Plasma keyhole welding is being developed for mechanized orbital pipe welding. This technique offers many advantages over conventional GTAW in that much thicker root faces can be fused. The WI originally developed synergic welding (the arc pulsing frequency is locked with the wire feed so that the welding current and wire feed rates can be carefully synchronized for pulsed welding). The current research on synergic welding is trying to extend the methods to open arc and short-circuiting arc GMAW welding.

Improved productivity of the SAW process is a goal in the UK as well as in the US. The research at the WI is centered on hot-wire and powder-metal-addition techniques and the development of equipment for narrow-gap SAW, all of which can potentially increase productivity. Finite element analysis has been used to predict the thermal cycle in the heat affected zone (HAZ) of SAW welds so that the effects of varying the welding parameters on, for example, grain size in the HAZ can be estimated. This substantially reduces the amount of experimentation that must be done.

The mechanical properties and fume-emission rates of typical flux cored welding wires have been determined with the aim of increasing the use of this technique for welding C-Mn steels. It has been found that good low-temperature fracture properties can be obtained with and without gas shielding, but more careful control of the welding procedure is required than with solid wire GMAW welding.

The WI feels that in narrow gap GMAW and hot wire GTAW welding processes the benefits of mechanized and automatic arc welding can be maximized with respect to a combination of a high output rate and low consumable and energy consumption. Research on these two processes continues, with many members now requesting feasibility studies for the application of the hot wire GTAW.

High-speed photography is being used to investigate the influence of major welding process variables--such as shielding gas composition, arc current, welding speed, and chemical composition of the filler- and base-metal--on the

arc stability and weld splatter. This is part of a large program attempting to solve the problem of variable weldability with certain types of steel and aluminum alloys. This program is continuing, but some interesting results have already been found. Different mechanisms are responsible for the arc instabilities in each of the different alloy systems. For example, with Al alloy filler wire, arc instabilities are caused by vapors from the high-vapor-pressure alloy elements such as Mg and Zn causing the molten droplets to explode during their transfer through the arc. These explosions result in unstable metal transfer and erratic welding.

The steel alloys can have a wide variation in arc instability, which can be caused by the presence of rare earth elements. These rare earth elements are used in modern steel making to control the shape and distribution of sulphide inclusions. Problems with weld splatter during $CO_2$-shielded welding of these materials have been reported. Again high-speed photography of the arc and oscillography of the welding parameters were used to obtain information about the arc and metal transfer stability. These revealed that droplet transfer was more irregular for rare-earth-treated steels. This problem can be greatly reduced by changing the shielding gas to Ar-15 percent $CO_2$ shielding gas but only at travel speeds below 300 mm/min. When the metal transfer occurs by the spray method (30 V, 310 A, Ar+15%$CO_2$), cerium-rich areas were believed to cause the formation of cathode jets on the plate surface; this in turn caused the droplets to be repelled in these regions, resulting in the excessive splatter.

Engineering Department

Fracture Research. The Engineering Department is concerned with the design of welded structures, their performance under applied loads (fatigue and brittle failure), and nondestructive testing.

The fracture research at the WI still favors the use of the crack tip opening displacement (CTOD) test method for the analysis of ductile fracture (this is because the approach is easier to use than other elastic-plastic fracture methods, it is more easily visualized, and it was easier to "sell" to the offshore industry, one of the WI's biggest sponsors). The CTOD is used to set tolerable flaw sizes in large structures. Safety factors of about two on the flaw size and conservative inputs for the operating stresses and environmental effects are actually used the design stage. Critical regions in the structure are identified based on CTOD, and once these regions are identified, specific nondestructive testing requirements are set for those regions.

The J-integral elastic-plastic ductile fracture method is also studied at the WI, especially the application of this method to short cracks. They find that the J-integral can only be used to predict fracture when the material fractures by completely ductile mechanisms, thus it is not useful for the ductile-to-brittle fracture transition temperature regime. The CTOD, however, has been developed to describe fracture in this temperature regime. Further, they have found that if completely ductile crack growth occurs, catastrophic fracture is very unlikely under any condition.

They are using wide plate tests (up to 100-mm thick) with and without welds, with and without defects to verify the failure criteria developed in the laboratory. (They have vast testing machines of up to 40,000 kN of force for the loading of these wide plates.)

This department is also studying dynamic crack initiation and arrest, fracture of weldments in offshore structures, defect assessment of girth welds for offshore pipelines, standardization of fracture toughness tests for weldments, effect of prior overload on fracture resistance, and development of a computerized database for fracture toughness data.

Fatigue Research. Most of the fatigue research is focused on problems with offshore structures; thus, random loading and corrosion effects of welded structures are actively investigated.

In many respects the fatigue performance of welded materials differs drastically from that of plain materials. These differences are due to: (1) pre-existing defects in welds, (2) tensile residual stress approaching the yield stress of the material, and (3) stress concentration near the weld (due to changes in the section thickness). A very obvious difference between the fatigue behavior of welded and nonwelded material is that the endurance fatigue life (cyclic stress for a life of $10^6$ cycles) of nonwelded material is known to increase with increasing tensile strength of the material. This is not the case for weldments because the fatigue endurance life is independent of the strength level of the steel. This is believed to be due to the fact that pre-existing defects in the weldments eliminate the crack-initation stage of fatigue fracture. Since the fatigue crack growth rate of steel has been shown to be essentially independent of tensile strength, and with weldments this is the only mechanism involved in

fatigue fracture, the endurance fatigue life of weldments does not increase with an increasing tensile strength.

The fatigue behavior of the materials used for offshore platform construction must be accurately known for the service environment, seawater. The WI has a very large research program which is studying the effects of this environment on the fatigue life of standard laboratory test specimens and test specimens which simulate the geometries of the actual structure. Randomly loaded tests of laboratory specimens (simulating wave action on the structure) which were both freely corroding and cathodically protected (-850 mV with respect to Ag/AgCl,) were performed on smooth (for endurance testing) and compact tension (for crack growth rate testing) test specimens. With freely corroding conditions the threshold stress intensity for crack growth, $\Delta K_{th}$, was reduced approximately 20 percent from its value of 250 $N/mm^{3/2}$ in air, while the simulated cathodic protection $\Delta K_{th}$ was restored to its value in air. This is probably coincidental because the increase in $\Delta K_{th}$ will be due in part to a presence of calcareous scale which forms on the crack surfaces during cathodic protection. This scale prevents full crack closure, which will reduce the effective $\Delta K$. The crack growth rate with cathodic protection was, however, not significantly lower than for the freely corroding samples where the crack growth rate was 7 to 10 times faster than in air.

The specimens which were designed to simulate the real welded structure and the experimental setup for these tests are shown in Figures 1 and 2. These specimens were loaded with a narrow band random load at a frequency of 1/6 Hz, typical of North Sea conditions. Three different environments were studied: freely corroding in artificial seawater (at 5°C to 8°C with the pH between 7.8 and 8.2); alternate immersion in seawater (6 hours) and then drying (6 hours) to simulate tidal wetting; and, finally, impressed current cathodic protection similar to that used for the standard laboratory test specimens. There is some controversy over how to present the results of narrow-band, random-loaded tests. The WI investigators chose to use a second order average of the load, i.e., root mean square. Considerable scatter in the number of cycles to failure exists in the data, but the fatigue strength appears to be independent of any applied mean stress, presumably because welded structures contain a high residual tensile stress irrespective of the applied stress. No difference in fatigue life was observed for freely corroding, intermittently immersed, and cathodically protected conditions. The endurance for each specimen was greater than would be predicted using a linear cumulative damage assessment (Miners Rule) based on the currently used design fatigue life curves.

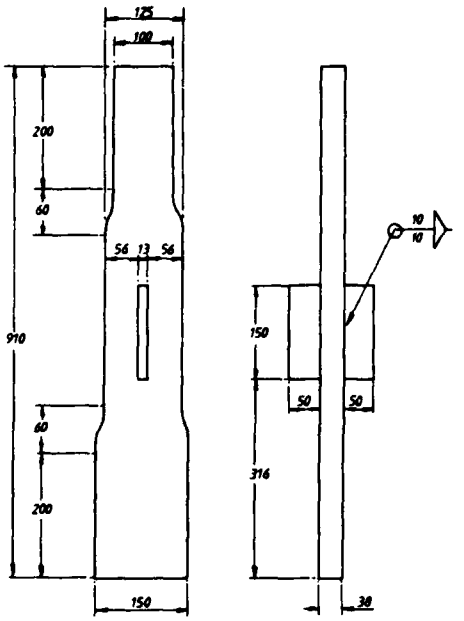



Figure 1. Specimen configuration; dimensions in millimeters (private communication from G.S. Booth, The Welding Institute, Abington, Cambridge, UK, 1984).

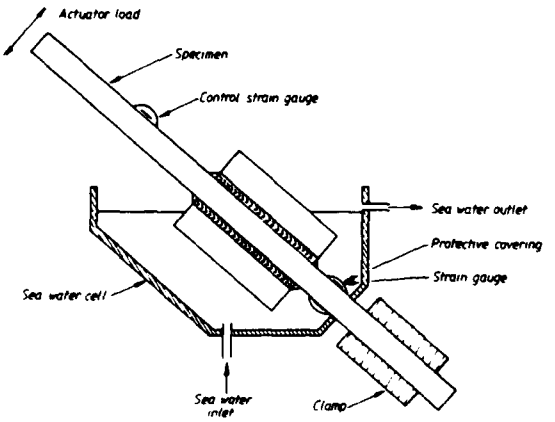



Figure 2. A longitudinal joint in the seawater cell (private communication with G.S. Booth, The Welding Institute, Abington, Cambridge, UK, 1984).

Many other research programs are in progress in this group. They include basic fatigue data on welded joints to be used in the development of a computerized fatigue database, low-cycle fatigue of welded joints in high hardness steels, and finite element methods for calculating the CTOD and the J-integral.

In its research on nondestructive testing the WI has developed a fully automated, computer-controlled testing system that is used to develop analytical routines for diagnosing and characterizing the size and shape of defects. An image processing system for computerized radiography has been developed to assist in the analysis of radiographs. Ultrasonic transducers have been developed which have exceptional near-surface performance and high lateral resolution. These are used for the inspection of welds in thin sections.

More information on projects in the Engineering Department can be obtained by writing to Dr. J.D. Harrison at the WI.

Sheet and Precision Processes Department

The research in this department focuses on the use and development of electron- and laser-beam welding, resistance welding, the welding of plastics, friction welding, and micro joining.

Electron-Beam Welding. The only research on high-power electron-beam (EBW) and nonvacuum electron-beam welding (NVEBW) in the UK is done at the WI. The current work on EBW involves a parametric study of the effect of various parameters (beam convergence angle, focus spot diameter, current density distribution profile at the beam source, position of beam focus with respect to the workpiece surface, beam deflection frequencies and amplitude, beam voltage and current ripples) on the weld quality and beam characteristics. This project is studying these beam-material interactions for carbon manganese steels, stainless steels, and nonferrous materials such as copper and aluminum alloys. The project includes the study of the above parameters and the development of equipment for EBW such as beam scanning systems, power density measuring devices, stable high-voltage supplies, and double focusing lens systems.

The development of NVEBW of C-Mn steels is limited to a weld thickness less than about 25 mm because of weld metal solidification cracking, which occurs as a result of the weld shape and solidification structure. Improvements to the beam shape at the workpiece are necessary to avoid this situation. The easiest way to improve the beam shape (avoid the scattering effects which occur as the beam passes through the air gap) is to increase the accelerating voltage and the beam power density. The WI is modifying its equipment to increase the accelerating potential to 300 KV. This necessitates a redesign of the electron gun and cable. It will also probably be necessary to increase the x-ray shielding provisions.

Welding Sheet Material. The high-speed magnetically impelled arc fusion technique for sheet welding has been studied for sheet thickness ranging from 0.2 mm to 1.2 mm. The method has only proven successful for sheet thicknesses less than 0.3-mm thick.

Laser welding of butt and T-joints of steel sheet up to 4-mm thick has been studied. All of the necessary welding parameters to assure high-quality welds have been successfully established. Laser beam spinning has been developed to minimize the misalignment problems caused by the small beam size. The misalignment that can be tolerated has been increased from 0.25 mm to 0.50 mm, and the maximum joint gap that can be welded has been increased from 0.12 mm to 0.3 mm.

Magnetically impelled arc butt welding for the straight butt welding of steel tubes has been established as a feasible joining method for both circular and noncircular tube sections in ferrous and nonferrous materials.

Plastics. A plastics-joining laboratory has been established in response to the increased use of plastics, especially in the automotive industries. Hot plate, ultrasonic, vibration, laser, and friction welding processes are being studied to assess their suitability for welding both amorphous and semicrystalline thermoplastics.

Other topics under investigation in this division include friction welding (especially for dissimilar metals and underwater), friction surfacing, diffusion bonding (especially for dissimilar and complex materials, such as fiber reinforced metals) and microjoining techniques for the connection of thin wires to semiconducting devices.

More information can be obtained by writing to Dr. K.I. Johnson, head of this department.

Materials Department

This department is the second largest in terms of research expenditures (£0.985 million); the Engineering Department is only slightly larger (£1 million). It has one of the most respected groups of welding metallurgists in the world.

The major research programs in this division include an investigation of

variable penetration in stainless and other steel welds, HAZ toughness in offshore and line-pipe steels, effects of steelmaking deoxidation practice on weldability and hydrogen-assisted cracking of steels, the role of inclusions in determining weld metal microstructures in low alloy steels, development of steels and filler metals which will allow higher speed welding, mechanisms of hydrogen-assisted cracking, corrosion of stainless steel weld metal, post-weld heat treatment of steels, and a new program on surface coating.

Only a few of these projects will be reviewed in this article. For more information, write to Dr. T. Gooch, the head of this department.

Surface Coating. Dr. Ian Bucklow is the principal investigator for a program to begin this year on surface science and technology sponsored by the Commission of the European Communities. Bucklow has been involved in research on sprayed coatings for over 10 years. His research at present is focused on sputter coatings, a few microns thick, that are designed to assist in solid-state and liquid-phase joining of metals. The WI has a downward sputtering chamber (target at the top of the chamber) which can accommodate substrates up to 150 mm by 150 mm. Currently a new upward sputtering chamber for use in coating semiconductor substrates is being installed.

Diffusion bonding of reactive metals, such as aluminum, is difficult because the surfaces are covered by stable oxide films which prevent true metal-to-metal contact. By removing these oxide films using ion bombardment in the sputtering chamber and then coating the surface with a less reactive metal which is soluble in the aluminum, a faster and better diffusion bond is formed.

It has been found that Ni or Ag coatings placed on the surface of two dissimilar metals to be diffusion bonded often prevent the formation of undesirable intermetallic phases at the bond interface.

Brazing alloys can be sputtered on the surface of two components (nickel-base superalloys, for example) which are then joined by liquid phase bonding (brazing) by heating to a temperature above the melting point of the brazing alloy.

The WI will be buying a hypersonic spraying system which will produce harder and denser coatings than from a "D" gun or by a high energy plasma. This system is called JETKOTE. In the US, the system is to be sold by the Cabot Materials Division.

Variable Weld Penetration. Research on variable penetration of welds in stainless and low-alloy steels has been performed in collaboration with the Arc Welding Department (discussed earlier). The cause of the problem is not fully understood yet, but some solutions have been proposed. Sulfur and oxygen have been found to be the most important elements influencing the variability of the stainless steels. These are the two elements present in these alloys which have the strongest influence on the surface tension of the liquid iron; an increase in either element lowers the surface tension. Convection in the weld pool can occur by Marangoni convection (a surface-tension-driven movement). Conflicting results were obtained on the role of surface-tension variation as the cause for the variable penetration; yet it has been found that if the sulfur content is 0.008 percent, or higher, no variable penetration occurs. Thus the WI can specify a solution to the problem, but does not yet understand why the solution works. (Note: this solution must come as a surprise to steel makers as they have been under pressure to reduce sulfur levels for years, and they are now able to control sulfur levels to 0.003 percent maximum without much difficulty.) All of the results to date indicate that the major cause for the variable penetration is due to variations in the fluid flow in the liquid weld pool. Results using EBW and laser-beam welding confirm that the problem is primarily due to material variations rather than arc variations as similar problems exist for these nonarcing processes.

Steel Weld Metal Microstructure. The control of steel-weld-metal microstructure through control of the filler metal composition and the welding process has been, and continues to be, studied at the WI. At present their attention is on the role nonmetallic inclusions play in determining the final microstructure of steel weld metal. It is known that a certain inclusion-number density is required to nucleate the desired aciccular ferrite and avoid the formation of side-plate ferrite or bainite. However, what is still under debate is how to achieve this critical inclusion number density and whether all inclusions, regardless of their chemical composition, act as nucleation sites for aciccular ferrite in the same way. This work at the WI is progressing at such a rapid rate that whatever I write now will have changed by the time this article is published. For an up-to-date report on this project, please write to

P.H.M. Hart, associate head of this department. The results of this project should help improve the productivity of the submerged arc welding process (a goal high on the US Navy's list of priorities).

HAZ Toughness. Perhaps the largest of the research projects in this division has just started. The factors that control the toughness in the HAZ of welds in high-strength, low-alloy steels will be systematically studied over the next 3 years. This project has been motivated by recent reports of poor HAZ toughness in offshore steels. Ten years ago this was not a problem, but since then the methods used for steel making have changed considerably. For example, calcium and rare earth elements are now added for sulfide shape control, and impurities are much lower than in the past. This a group-sponsored project (not a core project) which is very heavily subscribed (22 members). The results of this program will be immediately available to its sponsors only. If the US Navy has not yet joined in the sponsorship of this project, it should--because the results will be very relevant to the current high-strength, low-alloy steel program at David Taylor Naval Ship Research and Development Center.

Summary

Many projects at the WI (too many to discuss in this article) are directly relevant to the needs of the US Navy. Their work is motivated to a large degree by the needs of the UK's offshore industry. But since the problems facing this industry are very similar to those in the ship design, construction, and maintenance, the US Navy can obtain very useful information from the WI.

*3/19/85*

## WELDING RESEARCH AT SINTEF

*by Kenneth D. Challenger.*

The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology, SINTEF, has a strong research program on welding directed by Professor Nils Christensen. Christensen is near retirement, and at present it seems uncertain whether this research will continue. His colleague (and former student), Dr. Oystein Grong, is well qualified to maintain the high standards set by Christensen, but he is young and not tenured at SINTEF. Christensen's research has always been fundamental rather than empirical, a characteristic which is somewhat unusual in this field.

Hyperbaric Welding

A welding chamber capable of being pressurized to 45 bars (equivalent to the pressure at ocean depths of about 450 m) is being used to develop the welding parameters for underwater pipe welding. At 300 m, problems with shielded metal arc welding (SMAW) occur because of the increased absorption of C, H, and O in the molten weld metal. Even with low-hydrogen welding rods, such as E7016, the hydrogen level in the weld metal cannot be reduced below 10 ppm. This has necessitated the development of gas tungsten arc welding (GTAW) for these very high pressures (deep depths). Arc instabilities for the GTAW process occur at these pressures, but can be minimized by the proper selection of the shielding gases--He, Ar, $CO_2$, He+Ar+$O_2$. Ar has been found to produce the most stable arc but is not suitable for underwater welding because of the contamination of the diver's environment (it is difficult to separate Ar from the He). Therefore, the work at SINTEF is attempting to identify the shielding gas which is compatible with the diver's environment and improves the arc stability over a Ar shielding gas.

Implant Test

For many years, Christensen has been a proponent of the implant test for assessing the susceptibility for heat affected zone (HAZ) cracking caused by the presence of hydrogen. His position on this have not changed; he continues to use the test to assess weldability, select the correct steel compositions, and select the operational welding parameters. He feels that a separate assessment of metallurgical and operational factors must be made. The self-restraint tests (favored by The Welding Institute, Abington, UK) do not allow this separate assessment, because any changes in the welding conditions will simultaneously affect the state of stress and the metallurgical factors. The implant test has the advantage of completely controlling the stresses present without altering the welding conditions. The test results are obtained in terms of a nominal failure stress defined as the minimum value of tensile stress for continuous loading required for crack initiation or for complete rupture of the test bar ($R_{tr}$).

Various different test-bar geometries are used by investigators

worldwide. SINTEF investigators have used helical notches in the implant test bar to intensify the stress locally and make sure that this stress exists in all regions of the HAZ. This test has been used to characterize the HAZ cracking resistance of a wide range of steels with strength levels from about 370 MPa to over 1000 MPa. SMAW welds using rutile and basic electrodes, submerged arc welds (SAW), and $CO_2$ shielded welds were made with the implant test. This resulted in hydrogen contents from 1.5 ppm ($CO_2$ welding) to 25 ppm (rutile electrodes), and cooling rates in the 800°C to 500°C temperature range of 4 seconds to 12 seconds. Preheating was used to increase the cooling time below 300°C (allowing more time after the austenite decomposition for hydrogen to diffuse out of the steel). Preheating to only 100°C increased the cooling time in the temperature range of 300°C to about 100°C (105°C for the 100°C preheated material) from 60 seconds to 720 seconds.

In order to assess the reproducibility of the implant test, C-Mn steel (HT-1) was tested by five different laboratories (Figure 1). Considerable scatter is evident among these results, indicating some difficulty with the reproducibility of this test.

The results of the overall testing program indicate that the $R_{Ir}$ of the higher strength quenched and tempered steels has a stronger dependence on the hydrogen content than does the $R_{Ir}$ the lower strength C-Mn steels. Increasing the 800°C to 500°C cooling time improves $R_{Ir}$ for both categories of steels, but higher strength steels showed less effect from this cooling time. This is because increasing the cooling rate for the lower strength steels not only allows more time for hydrogen diffusion out of the weld, but also changes the microstructure of the HAZ. But with the high-strength steels, martensite is formed at all cooling rates investigated, so the only effect of cooling rate is to vary the hydrogen content in the HAZ.

Preheating to 100°C is a very effective way to increase $R_{Ir}$. For a steel with a yield strength of 780 MPa, the $R_{Ir}$ with 3 ppm hydrogen in the weld metal increased from 263 MPa with no preheating to 459 MPa with the 100°C preheat.

Christensen feels that the implant test is useful for comparing various steels, hydrogen levels, welding conditions, and preheating effects. He has attempted to analyze the state of stress in an implant test bar and then compare that to what has been measured in actual welds. By definition, the implant rupture strength is the nominal stress at rupture. For a circumferential notch of the geometry used by SINTEF the stress concentration factor has been estimated to be 4.8; with the threaded version of the implant test bar, this would be reduced to about 2.4. However, since local plastic deformation at the root of the notch is likely and the extent of this deformation will depend on the yield strength of the material, the exact stress concentration cannot be determined without information on the plastic deformation behavior of the material. Therefore, the determination of a safe implant rupture strength from first principles is very difficult, and for the near future the usefulness of this test will be for comparison only. It can be used for design only when previous experience is available with the steel and welding process. My own opinion is that the implant test's utility for avoiding HAZ cracking is comparable to the Charpy V-Notch impact test's use in avoiding brittle fracture: both require considerable experience before the information can be safely applied to design. Further, in my opinion, the implant test will never be used to assess the integrity of actual welds, but it is a good method to compare materials and variations in welding methods.

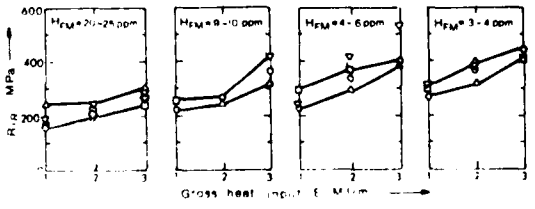



Figure 1. Comparative testing of steel HT1 in five laboratories (from Christensen and Simonsen, 1981b).

## Weld-Metal Chemistry

Many complex chemical reactions occur between the time a molten droplet forms on the welding electrode and the time it solidifies as part of the weld metal. These reactions take place at the electrode, in the arc plasma, and in the weld pool. To reliably predict the final solidified composition of the weld metal from the starting chemical composition of the welding wire or electrode, one

should know these reactions and the factors that influence them.

Dr. O. Grong has developed an experimental technique, based on a "melt spinning" apparatus used for producing amorphous metal ribbons (rapid solidification technology), which allows him to rapidly crystallize metal droplets in the absence of the weld pool. Thus, the reactions which normally occur in the weld pool can be assessed by comparing the chemical composition of the chilled droplets to that in normal weld metal. Many different shielding gases, including various combinations of $Ar+CO_2$ (from pure Ar to pure $CO_2$) and $Ar+O_2$ (from pure Ar to Ar+30% $O_2$), were evaluated using gas metal arc welding (GMAW). The findings are as follows:

1. Oxidation of carbon. For the case of carbon content only, the electrode-tip composition can be determined, which allows the reactions involving carbon at all three stages to be separated. Figure 2 clearly indicates that all of the carbon loss occurs by reactions which occur at the electrode tip. This loss must be from CO formation during the formation of the metal droplet, most probably at the hot surfaces facing the arc. The carbon loss appears to saturate when the shielding gas contains about 10 percent $O_2$. This is presumably due to a buildup of CO in the surrounding atmosphere (when the CO reaches a certain pressure the oxidation of carbon will cease). The reason for the lack of carbon reactions in the arc plasma is probably an inadequate supply of oxygen.

2. Oxidation of silicon and maganese. The loss of silicon occurs mainly in the liquid weld pool (Figure 3). These losses are believed to be due to SiO formation. The loss of manganese is shown in Figure 4. Note that the loss in the chilled metal is independent of the oxidation potential, indicating that this is mainly due to vaporization losses. Very large amounts of manganese are also lost in the weld pool as a result of deoxidation reactions.

3. Oxygen content. This study revealed that any oxygen pick-up must be occuring at the electrode tip because very little difference in the $O_2$ content exists between the chilled metal and the as-deposited metal. (The previous results on C, Si, and Mn also indicated a lack of interaction with $O_2$ in the plasma.) As expected, the $O_2$ content in the metal increased with the $O_2$ potential in the shielding gas.

This type of research is greatly needed in order to understand the

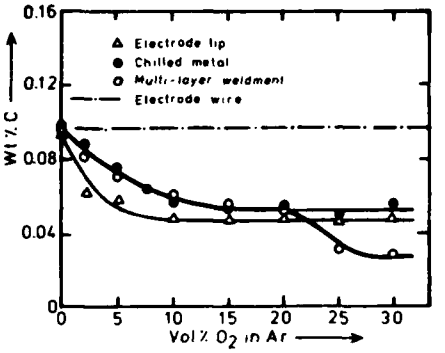



Figure 2. Carbon content versus oxygen potential at various steps in the weld process (from Grong and Christensen, 1983).

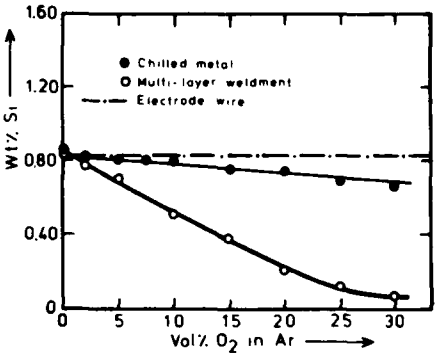



Figure 3. Silicon content of chilled metal and as-deposited weld metal versus oxygen potential of the shielding gas (from Grong and Christensen, 1983).

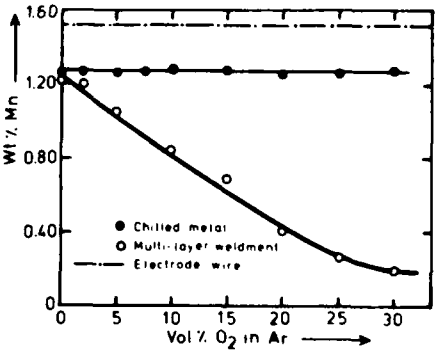
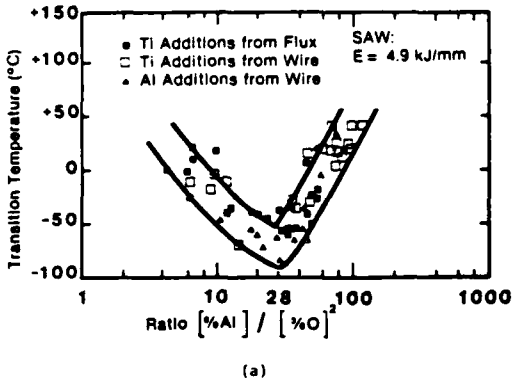



Figure 4. Manganese content of chilled metal and multilayer weldment versus the oxygen potential of the shielding gas (from Grong and Christensen, 1983).

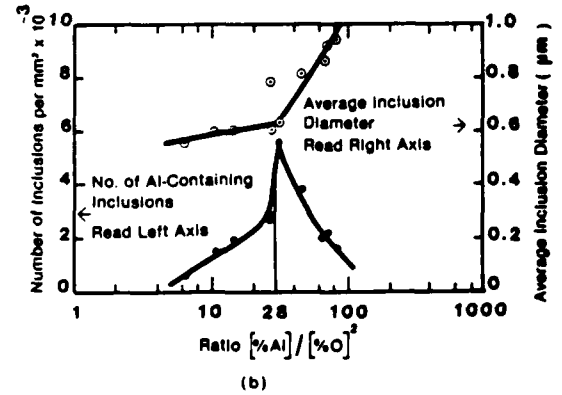
complex reactions that are occuring during fusion welding.

The effects of dioxidation practice on the microstructure of steel welds will be examined in a new project that has not yet begun. The research should provide very important information about the effects of dioxidation practice on the nonmetallic inclusions present in steel weld metal and about the effect of these inclusions on the microstructure of the weld metal. This work should provide useful information for the US Navy's research projects on high energy SAW and high-strength, low alloy steel development.

Grong has reviewed the literature on this subject and has observed some very interesting relationships between the ductile-to-brittle transition temperature (C-Mn steel weld metal) and the ratio between Al and $O_2$ contents (Figure 5a).




(a)




(b)

Figure 5. Relationship between the weld metal $[\%Al]/[\%O]^2$ ratio and: (a) the 35J Charpy V-notch transition temperature, (b) the inclusion size distribution and number density. Data from Terashima and Hart (micro-alloyed SA steel weld deposits) as analyzed by Grong and Matlock (in press).

The lowest transition temperature occurs at a value of 28 for the ratio $[\%Al]/[\%O_2]^2$, which is also the point where the inclusion-number density reaches a maximum (Figure 5b), this clearly indicates a relationship between the inclusion-number density and weld-metal microstructure.

In this work Grong proposes to study the effects of deoxidizing with Ti and Al on the inclusion size and distribution using GMAW with Ar+5% $CO_2$ shielding and various flux compositions for SAW. He hopes to start this research in about 6 months.

Summary

The welding research at SINTEF is more fundamental in nature than most welding research in Europe. This is somewhat surprising since it is guided by industrial needs. It is very germane to the US Navy's needs on this topic and thus deserves continuing attention.

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*3/18/85*

# Mathematics

## NONLINEAR DIFFUSION AT LEIDEN

*by Charles J. Holland. Dr. Holland is the Liaison Scientist for Applied Mathematics/Computational Science in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on reassignment until December 1985 from the Office of Naval Research, Arlington, Virginia, where he is the Deputy Division Director of the Mathematical Sciences Division.*

Professor L.A. Peletier heads a small group of researchers at the University of Leiden, The Netherlands, doing important work on the modeling and

analysis of nonlinear diffusion-reaction processes. An essential feature of these problems is that the diffusion coefficient may vanish over a range of parameter values. This degeneracy allows for a more realistic finite speed of propagation or dispersal, but at the same time requires a more sophisticated mathematical analysis using appropriate weak formulations of the partial differential equations modeling the phenomena.

In this article, I will give a brief physical motivation for studying these problems and then discuss in some detail two particular classes of phenomena that have been investigated recently by the Leiden researchers.

## Background

Until recently, much of the modeling of physical diffusion processes and the associated mathematical analysis has been based on a continuum-mechanics formulation with the assumption that the diffusion process is modeled by linear diffusion. In models of heat flow, this assumption is based on physical experiments which tend to show that the rate of flow of heat is proportional to the gradient of the temperature. As a consequence of these assumptions, the general heat equation, $u_t$ = div (D(u) grad u), is linearized by setting D(u) equal to a constant.

In recent modeling of many physical processes (flow through porous media, electron heat conduction, diffusion in plasmas) it has been necessary to modify the assumption of linear diffusion to more realistically capture the observed physical phenomena. Instead of linear diffusion it is sometimes assumed that the diffusion coefficient is proportional to some power $D(u)=Cu^k$. The case $k>o$ corresponds to slow diffusion while the case $-1<k<o$ corresponds to "fast" diffusion. Mathematical analysis of the slow diffusion case establishes that if the initial data have compact support, then so will the solution for all time. Thus there is a finite speed of propagation of the flow. The terminology "slow diffusion" may be somewhat misleading since the diffusion process, while propagating at a finite speed, may not be slow compared to other processes in a physical environment (such as the speed of sound).

## Research at Leiden

Peletier and his colleagues have extended this analysis beyond the case of simply "slow" or "fast" diffusion of one species. An essential feature of the problems they consider is that the diffusion coefficient may vanish, allowing for the possibility of a finite speed of propagation.

In the first problem area, Peletier and Bertsch of Leiden and P. de Mottoni of the Università dell' Aquila have been investigating the appearance and disappearance of a "mushy problem" in the Stefan problem with heating in the case where the diffusion process is nonlinear and degenerate. The mathematical problem studied is

$$u_t = (A(u))_{xx} + f(x,u) \text{ in } (0,1)\times(0,\infty),$$

with boundary conditions $A(u(0,t)) = A(u(1,t)) = 0$ for $t>0$ with non-negative initial conditions. In this setup, u represents the enthalpy and A(u) the temperature of the material. The function A is assumed to be nondecreasing and, moreover, to take the constant value 1 on some interval (a,b) where b may be infinite. If b is finite, then one has a two-phase problem; otherwise, the problem is one phase. In this setup, value 1 represents the melting temperature of the material so that if $A(u)<1$ the material is solid and if $A(u)>1$ the material is liquid. There is considerable interest in determining the existence and properties of the "mushy region" of the solution, which is defined to be the interior of the set where $A(u(x,t)) = 1$.

Since $A(u) = 0$ on (a,b), the equation for u is a degenerate diffusion equation. Most previous investigations have been restricted to the case where A' is zero at a single point as in the slow diffusion case described above. The degeneracy requires a weak formulation of the equation. Using this formulation and some additional technical assumptions, they are able to show in the two-phase case (b is finite) that interior heating (f>o) sufficiently strong to cause melting will result in the development of a mushy region which disappears in finite time. This theoretical work confirms some earlier numerical work of Atthey (1974) for special initial data. With no interior heating but with the boundary condition $A(u(1,t)) = R>1$ (so that the material is also in two phases), they are able to show that any initially existing mushy region disappears in finite time.

In another problem area, Peletier and Bertsch, along with D. Hilhorst (University of Paris-South, France) and M. Gurtin (Carnegie-Mellon University, US), have studied the diffusion of interacting species (for example, chemical or population species) that disperse in response to total population pressure. They consider the case of two species with population sufficiently dense that a continuum theory is applicable and assume that the species are

undergoing dispersal on a time scale sufficiently small that births and deaths are negligible. This assumption leads them to consider the equations

$$u_t = k_1 \text{ div } (u \text{ grad } (u+v))$$
$$v_t = k_2 \text{ div } (v \text{ grad } (u+v)),$$

where $u = u(x,t)$, $v = v(x,t)$ represent the population of the two species. They further restrict themselves to the case of one space dimension and assume no-flux boundary conditions to model the fact that the species are unable to cross the boundary.

Under these assumptions, they establish the existence of at least one solution in which the two species are segregated for all time, provided that they are segregated initially. This result is quite surprising since it only requires that the initial data be segregated and is independent of the values of $k_1$ and $k_2$. To derive these results, they work in a weak formulation of the problem. They do not rule out the possibility of solutions which mix--even for segregated initial conditions. They conjecture that mixing in this case cannot occur, but are currently unable to establish uniqueness of the initial value problem in this weak formulation.

They have not studied the above problem for nonsegregated initial data except for the case $k_1=k_2$, which is much simpler to analyze. In that case, adding the differential equations for u and v, one obtains a single equation for the total population $P = u+v$. Using this reduction, they are able to prove uniqueness within the class of all solutions and can show that solutions which begin mixed remain so for all time.

Conclusion

Peletier and his colleagues are analyzing mathematically the qualitative properties of solutions to various degenerate nonlinear diffusion processes. This basic work, while on model problems, should provide insight concerning the appropriate modeling of realistic complex physical processes and their associated behavior. Let us hope that the diffusion of these techniques and results into the engineering and physical science communities will not be of a degenerate diffusion type with an extremely slow speed of propagation.

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*3/22/85*

## MATHEMATICS RESEARCH AT CWI, AMSTERDAM

*by Charles J. Holland.*

The Netherlands' Center for Mathematics and Computer Science recently has received stimulation grants to transfer advanced mathematics to Dutch industries and governmental agencies. The CWI (for Centrum voor Wiskunde en Informatica) conducts basic and applied research in various areas of the mathematical sciences, with special attention to those areas which may have applications in The Netherlands.

In this article I will give an overview of the center and then focus on the research activities in numerical analysis, including several projects which are involved in the transfer of advanced mathematics to applications.

Background

The CWI, located in suburban Amsterdam, is the research center of the nonprofit Foundation Mathematical Center (SMC for Stichting Mathematisch Centrum). It was founded in 1946 through the efforts of Professor van der Corput to give a focus to the Dutch mathematical community, which had been fragmented during the war. Until 1983 the SMC was known as the Mathematisch Centrum, but the name was changed in 1983 to give a better description of its research activities. Since the center's founding, computer science has been an important activity, so the name change does not reflect an expansion of the research interests. In fact, the first Dutch computer was designed at the center and was later built by Philips.

Organization

The current scientific director of the center is Professor P.C. Baayen, who heads the six research departments: Pure Mathematics, Applied Mathematics, Mathematical Statistics, Operations Research and Systems Science, Numerical Mathematics, and Computer Science. The total staff is approximately 150, including support personnel. The research staff of approximately 80 is made up of approximately 40 percent full-time appointments. The remaining 60 percent are divided among postdoctoral personnel,

who have a limited term appointment of 3 years, and master's level students. Typically, these master's level students have completed 6 years of course work and are given a 4-year appointment to write a doctoral thesis.

Funding

In 1983 the budget of the CWI was approximately 13 million Dutch guilders (currently there are about 3.6 Dutch guilders to the dollar, but in 1983 there were approximately 2.8). Of this total, approximately 11 million guilders were received directly from the Dutch government through The Netherlands Organization for the Advancement of Pure Research (the ZWO), which can be considered the equivalent of the US National Science Foundation (*ESN* 38-8:438-442 [1984]). The remaining funds, approximately 15 percent of the total budget, arise from various sources, including contracts, publications, and courses.

Currently, additional funds are available from the new Dutch program to stimulate research transition to industry. If an industry expresses interest in a particular research application, then the Dutch government, through the Foundation for the Technical Sciences (STW), will provide support to enable its transition. In this arrangement, the industry is not forced to provide cost sharing, but only to interact with the research personnel. There are currently six of these projects ongoing at CWI. A larger source of additional funding is a 5-year grant for 2 million guilders annually as a result of CWI's being designated by the national government as the Dutch center of excellence for computing.

Trends

Under the direction of van der Corput, the CWI started as a fairly applied institute; as mentioned above, the first Dutch computers were developed there. In the past, efforts shifted to a more theoretical nature, but that trend may be reversing. Two reasons expressed for this shift were: (1) many mathematical tools have been developed which are now capable of being applied, and (2) there appear to be more interesting mathematical problems in industry. But another reason for this shift is that there are the additional funds from the Dutch government to work on these problems of interest to industry.

Research Activities in Numerical Analysis

In the rest of this article, I will concentrate on the activities in numerical analysis with a brief overview of some of the other departments. Professor P.J. van der Houwen heads the Numerical Mathematics Department. Researchers there are interested mainly in initial and boundary value problems for partial differential equations and in numerical software development. The topics under investigation are a combination of both theoretical research and applied (or contract) research.

Theoretical work on initial-boundary-value problems is concentrating in the areas of stability and convergence of numerical schemes for solving nonlinear differential equations. This stability and convergence work relies heavily on 1975 work of G. Dahlquist and has been reported in a monograph by K. Dekker and J. Verwer (1984).

The applied work on initial value problems is focusing on two-dimensional hyperbolic schemes with reduced dispersion and on the incompressible Navier-Stokes equations. In a project sponsored by the STW, the goal is to apply the theoretical work undertaken at the CWI to develop an efficient vector code for the Cyber 205 for solving shallow-water equations. This code, being developed under the stimulation scheme discussed above for the National Hydraulics Laboratory, will be an explicit scheme to exploit the specific characteristics of the Cyber 205, the scheme will replace a very good sequential scheme using an alternating direction implicit scheme. The shallow-water equations consist of three linked partial-differential equations for the velocity vector and the rise of water level under the influence of tides or winds. The problems, of tremendous importance to The Netherlands, is to be able to calculate the velocity vector and rise of water level as functions of time and place for any configuration of coast, floor profile, and obstacle as well as for given external forces such as wind and friction.

Theoretical research on boundary-value problems is concentrating on the development of multigrid methods. This work has emphasized general linear second-order elliptic partial differential equations on a rectangle in two dimensions with either Dirichlet, Neumann, or mixed boundary conditions.

In cooperation with the Delft University of Technology, the researchers have developed two portable algorithms (not machine dependent) for these problems. The first version is intended for the usual sequential (scalar) computer, while the other is aimed at vector computers (such as versions of the Cray or the Cyber 205). In both cases they have not used features that are machine dependent but have instead written the

program in the most elementary and portable Fortran. This means, for the vector code, that they have used the auto-vectorization capabilities of the Fortran compilers. Of course, a faster multigrid algorithm could be written if one restricts oneself to one machine and, even faster yet, if one restricts oneself to a particular equation. For example, Barkai and Brandt (1983) have constructed a special multigrid program for the Cyber 205 which solves only the Poisson equation.

The contract work on boundary value problems is concentrating on the development of a Cyber 205 code, to be used by the Dutch National Aerospace Laboratory for solving the steady Euler equations describing nonviscous gas flow problems.

Work on software development is using a European community grant for the development of ADA software for numerical algorithms. This is a joint project with the UK's Numerical Algorithms Group (NAG) and National Physical Laboratory, and Trinity College in Dublin, Ireland.

Other Research

Professor J. K. Lenstra heads the Operations Research and Systems Science Department, which concentrates in combinatorial optimization, systems and control, networks and queues. The unifying theme in this research is the development of techniques that can aid in decision making. One special focus of the department is the investigation of the use of parallel computer architectures and algorithms for applications to operations research problems. While there has been significant research activity in the investigation of parallel algorithms for modeling large-scale physical systems (for example in computational fluid dynamics), the application of parallel algorithms to the operations research arena appears relatively new. The researchers expect that their future research in this field will examine the parallelization of enumerative methods, such as dynamic programming and branch and bound. They are currently interested in applying their algorithms to existing mulitiple-instruction multiple-data machines such as the Denelcor HEP.

The Applied Mathematics Department, headed by Professor H.A. Lauwerier, is concentrating in biomathematics, stochastic aspects of dynamical systems, and asymptotics and applied analysis. In the last area, N.M. Temme and C.G. van der Laan (1984) have published a CWI tract discussing the numerical computation of special functions such as the Euler gamma function, the exponential integrals, and the error functions.

The fundamental work in the Mathematical Statistics Department, now headed by R. Gill, has been concentrating on semiparametric statistics to model real-life cases in which one part of the situation has a very specialized structure and the other part is unknown. Gill is interested in generalizing the concepts of maximum likelihood to nonparametric cases. The applied work in the statistics department is concentrating on discriminant analysis; the researchers want to develop automatic classification schemes. Gill reported that he would like to see his department move more in the direction of computational methods in statistics, including stochastic geometry and the analysis of images. He reported, however, that he was having difficulty in obtaining professionals in these areas.

Conclusion

Researchers at the CWI are doing an excellent job of combining basic research with applications. This is especially evident in the work in numerical analysis, which is leading to the development of very efficient codes for practical fluid dynamics applications.

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*3/22/85*

# Mechanics

## SHIP-PROPELLER RESEARCH AND PRODUCTION IN SWEDEN

*by Patrick Leehey. Dr. Leehey is the Liaison Scientist for Naval Architecture*

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Sweden's Statens Skeppsprovningsanstalt (SSPA) and the firm KaMeWa are using modern water-tunnel techniques for dynamic hull-propeller interaction studies. KaMeWa is also noted for its excellent controllable-pitch propeller production. Swedish experience in tests of hull and propeller models together with cavitation scaling is providing guidance to US water-tunnel developments.

SSPA

At SSPA, the Swedish Maritime Research Center in Göteborg, my host was Dr. Carl-Anders Johnsson, who is principally responsible for the design, construction, and operation of the very large water tunnel at the facility. This is the most interesting experimental facility at the SSPA. It was the one used by the US Navy for determination of the recent difficulties with excessive vibration from propeller cavitation on a new class of auxiliary ships. The need for this capability in the US has in part influenced the design of the new Large Cavitation Channel at the David Taylor Naval Ship Research and Development Center, Bethesda.

The SSPA facility has both high-speed and low-speed test sections. The large section has a 2 to 1 area contraction ratio, and the high-speed section has a 9 to 1 area contraction ratio. The low-speed test section and an approximate 8-m surface-ship hull model were in place. The propulsion system was of counter-rotating design so that both an internal propeller dynamometer and a sting-type dynamometer came up from the stern. The high-speed test section was sitting nearby. It was prepared for the measurement of supercavitating propellers at shaft angles up to 15 degrees. These propellers are used on Swedish torpedo boats.

The windows in the low-speed test section of the tunnel were of somewhat unusual design. They had both very large and very small set screws which were used alternately, depending upon whether a vacuum or pressure was created in the test section of the facility. There was a wooden surface plate at the water surface above the hull model. The researchers can make dynamic pressure measurements directly upon the model hulls with the propellers operating.

They have no special facilities for air content control, and their only present measurement technique for air content is a standard van Slyke apparatus. Their method of reporting air content is in milliliters per liter relative to the same ratio for atmospheric pressure saturation conditions. On this basis they operate in a range from 0.05 to 1.1. This is a rather strange way of reporting air content since the actual test conditions are far from atmospheric. Curiously, they also lack any laser Doppler anemometry system. Otherwise, the facility is very well instrumented. They also have capability for digitalized fast Fourier transform (FFT) analysis. Their propulsion motors are quite elegant. They can test ship models with up to three propulsion units installed.

It is interesting to note that they do not generally make spectral density reductions of their data. The problem seems to be that the cavitation is frequently sufficiently intermittent that they may or may not have cavitation over one integration time for an FFT. They tend to rely more on histograms showing the percentage distribution of pressure amplitudes as measured on the hull model. They also correlate this with full-scale measurements. They find good correlation of the highest amplitude pressure fluctuations between model to full scale. However, the root mean square (RMS) value for full scale is considerably greater than that for the model.

Dr. Lars Larsson at the SSPA has been using streamline coordinates in numerical calculations of three-dimensional boundary layers. He has succeeded in producing the isovelocity profiles in the stern region of a merchant ship hull that correspond quite reasonably with measurements on model scale of the same boundary layer profile. However, both were without propulsion. He believes that it is ultimately necessary to measure the wake during self-propulsion, and then to extract the induced velocities of the propeller. The present comparison was obtained using measured pressure distributions of the hull model in the boundary layer calculation.

In the course of a 6-year research program on various aspects of three-dimensional boundary-layer calculation and measurement, Larsson has developed a floating-element resistance measuring gauge. It is a square, 200×200 mm, with gaps of 0.2 mm. The technique used is to restore the device under test to the original position by micrometer adjustment, to use a microscope for observation of the gap, and then to measure the drag using strain gauges. The SSPA uses

Spaulding's Phoenix program for three-dimensional mean flow calculations. We discussed the method of accounting for the transition zone between laminar and turbulent flow. Here they took exception to the Michel-Smith exp 9th criterion and found, for example, in their work in their outdoor tank with some surface disturbance due to wind that an exp 5th power was sometimes more appropriate.

KaMeWa

KaMeWa is an acronym for Karlstadt Mekaniksa Werkstad AB in Kristinehamn. My host was Mr. Orvar Björheden, who is the naval architect manager of the marine laboratories at KaMeWa.

This is a 150-year-old firm whose original work was in the design and construction of hydroelectric turbines. It still does this work, but 75 percent of its present business is in marine products, most of which are controllable-pitch propellers. They are a part of the Axel Johnson group of companies, which are widely diversified in areas such as shipping, computer services, and commodity trading. The US affiliate of this company is the Bird-Johnson Company of Walpole, Massachusetts. The Bird-Johnson people were the designers and builders of the controllable-pitch propellers for the *Spruance* class destroyers.

Besides controllable-pitch propellers, the principal marine products of KaMeWa are thrusters and water-jet propulsion units. The controllable-pitch propellers form a geometrically similar series, increasing from a hub size of 132-cm diameter in 9-percent steps up to 240-cm diameters. These are actually produced, and there are designs going up as large as 280-cm diameter. By way of illustration, the *Spruance* class destroyers use a hub size of 157-cm diameter, whereas the largest sizes currently constructed are for slow-speed tankers. The basic mechanisms have been redesigned, probably because of a spindle torque problem that occurred several years ago on a US destroyer escort. It is also particularly impressive that most of the current commercial and military KaMeWa propellers are designed with very extreme skew, undoubtedly to reduce vibrations at the blade passing frequency. The company is using the computer programs following design procedures of Professor Justin Kerwin of the Massachusetts Institute of Technology.

The thrusters are of two types. One is essentially a Kort-nozzle configuration. It is used, for example, for bow thrusters on ferry boats and also for positioning thrusters on offshore drilling rigs. Other types, however, are of open propeller design with the thrust capability used for ship control. Their newest line is the water-jet propulsion systems. These are appreciably different from the US Rocketdyne designs, which involve torpedo-type injection. The KaMeWa designs have a smooth suction port in the hull and exhaust overboard astern into the air. The jet velocities are lower and the diameter is greater than in the Rocketdyne designs. These thrusters are used in a variety of applications, particularly for shallow water work on more conventional ships, but also on catamaran ferries and surface effect vehicles.

I visited the shops of KaMeWa and saw a variety of marine propulsion devices under construction. The machining facilities are almost entirely numerically controlled; the work force is approximately 300 in the shops, and there are approximately 300 in the engineering force. Because of the heavy emphasis on numerically controlled machining, it seemed almost as if the shops were three-quarters empty, but the production work was proceeding apace.

Their earlier propellers were almost entirely of stainless steel; however, the present production is 80 percent in bronze propellers and only 20 percent in steel. They produce approximately 150 propellers per year. Their numerically controlled blade-machining techniques provide the final cut, which is at approximately 1-mm spacing; the last polishing operations leave them with about a 3-μ RMS surface roughness, but with some slight waviness.

I also visited the hydrodynamic test facilities. They have two very large water tunnels. The smaller one is of conventional design and is used for most of the testing of commercial-ship propellers. The larger facility is a free-surface type with a very large horizontal diffuser section downstream. This diffuser section is also used for in-place testing of thrusters with no use of the main impellers but with vacuum being drawn on the facility. Their only air-content measurement system is a van Slyke apparatus. They do provide for air bubble injection in the free-surface facility but not in the conventional test facility. I saw no laser Doppler anemometry equipment in use. They concentrate primarily upon steady-state data, although they do take a limited amount of dynamic data from piezoelectric pressure transducers set flush in stern forms. They do not use an entire ship hull but use only the after one-quarter portion. They must

simulate the forward boundary layer by the use of screens.

Conclusion

The facilities for research at the SSPA and for research and production at KaMeWa give Sweden a very strong capability in ship propulsion.

*3/21/85*

# Physics

## LASER DEVELOPMENT AND QUANTUM ELECTRONICS AT FRANKFURT

*by Paul Roman. Dr. Roman is the Liaison Scientist for Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on assignment until September 1987.*

Even though the visitor may marvel at the sight of recently excavated Roman ruins and of a reconstructed medieval town center, Frankfurt am Main, West Germany, is a very modern town, built upon the ruins of World War II. Its university and the various independent research labs focus on front-line topics and development projects, are well supported, and cooperate smoothly with industry. In my pursuit of notable European centers for quantum optics and related areas I found two outstanding research centers in Frankfurt: the Battelle Institute and the quantum-optics/electronics/solid state physics cooperation within the Physics Faculty at the Goethe University. This article reports on pioneering research at these institutions done in the fields of transversely excited atmospheric pressure (TEA) lasers, gas transport lasers, miniaturizing of laser devices, and a variety of microscopic aspects of nonlinear optics, including bistability research. Clearly, these are all subjects of interest for the US optoelectronics research community.

Lasers at Battelle

The international Battelle organization, with two centers in the US, one in Geneva, and one in Frankfurt, is the largest private research organization in the world. It has over 7000 employees and yearly expenditures of more than $350 million. The legally and financially independent institute at Frankfurt, established about 30 years ago, concentrates on R&D and on technical-scientific advising and training for industry and government. The task group for lasers and optics cooperates strongly with the divisions for Physico-Technical Procedures and for Applied Solid State Physics. The senior person of the task group is Dr. K. Gürs, who is probably the most experienced laser person in Germany. He got involved with solid state lasers as early as 1959 (while at Siemens), and joined Battelle in 1967. Under his leadership the institute developed 65 lasers and laser systems, more than any other single lab in West Germany. A listing of the most important development projects is impressive:

- Pulsed and CW ruby and glass lasers
- Compact, reliable Nd:Yag (up to 140 W in CW, or 1000 Hz rep.)
- Pulsed and CW CO, HF/DF, HCl, $N_2O$ lasers
- Passively or actively stabilized and injection locked molecular lasers.

But the current emphasis is on various $CO_2$ devices such as TEA lasers and gas transport lasers. I shall now review this work.

TEA Lasers. To obtain a good beam quality from TEA lasers, one must guarantee a uniform gas discharge over the whole discharge region. In addition, high efficiency requires that the process of excitation of the $CO_2$ and $N_2$ molecules and that of generation of free electrons (necessary for the excitation) are optimized separately. To produce a self-sustaining gas discharge, electron energies are needed which are ineffective for excitation of the laser gas, and this results in low laser efficiency. Therefore, it is advantageous to generate free electrons by pre-ionization and to accelerate them subsequently in a transverse electrical drift field. Application of ultraviolet (UV) light is the most promising approach, especially if the UV radiation is generated in a corona discharge.

Unlike the earlier devices, the recently developed TEA lasers at Battelle do not use separate trigger wires but integrate the means for generating the corona discharge into the walls of the discharge chamber. Either isolated metal parts of the housing (having the potential of one of the electrodes) are arranged along the other electrode, or such metal parts are imbedded into the wall of the discharge chamber which is made of an insulating material. For example, in one such arrangement, the metal frame and the lower electrode are

grounded. To get higher output power, several discharge systems can be used in serial connection. By using a set of four NaCl prisms in the inner beam path and tilting the end mirror, the laser can be tuned to more than 60 lines. To obtain a high repetition rate, the laser gas has to be quickly exchanged and, during circulation, cooled. In one model, the Gürs group replaced the side walls by a sequence of isolated rods and arranged for five ventilators to provide circulation. A typical laser of such a construction generates 10 J at 10 Hz (or 3 J at 30 Hz), corresponding to a mean power of 100 W. The specific energy is 28 J/liter and can be considerably improved. Another development project resulted in a laser of similar performance but with much smaller dimensions, compact and inexpensive. These features have been achieved simply by having the gas inlet and outlet not in the side walls but in the bottom of the discharge chamber on both sides of the lower electrode. I admired an even more compact version suitable for space applications. It consists of four discharge tubes with a common gas storage container and uses a heat pipe for cooling; tuning is effectuated with a stepping motor. It has a 20-W output and a very long lifetime.

Gas Transport Lasers. Another current research effort at Battelle is the construction of high-power, CW-operated, $CO_2$ gas transport lasers. In conventional lasers, the gas is cooled through the wall of the tube, which is rather ineffective. This is a drawback because, for a variety of reasons, the gain, power output, and efficiency of a $CO_2$ laser will substantially decrease with temperature. All measures to increase the output of a conventional design, such as increasing the cross section or the excitation power, simultaneously raise the gas temperature so that the power cannot exceed a certain maximum value per unit length of the tube. Consequently, high-power $CO_2$ lasers are extremely long and unwieldy for many applications. Gürs, about 8 years ago, calculated rigorously the effect of temperature variation on the power and efficiency and, based on these results, initiated experiments that led to effective cooling by exchanging the laser gas, in devices now known as gas transport lasers. At present, two such machines are under development.

One solution, the transverse system, uses impellers of tangential blowers. The blower wheels almost completely fill the interior of the essentially cylindrical casing. The housing is water-cooled and furnished with lamellas extending in the flow direction. The gas is circulated also in the space between the blower wheel blades and the wall of the casing. It flows through an excitation chamber equipped with 17 separate electrodes on one side and one common counter electrode on the other side. The laser resonator is folded, and it covers somewhat more than the whole excitation region. The current power output is 1 kW.

It can be calculated that, due to an incomplete conversion of the excitation energy into laser energy, losses arise in the machine. Therefore, additional experiments are now being carried out with a longitudinal device. In this system the laser gas is pumped off from the center of the tubes and flows with high velocity directly into the inlet of a radial blower. The axis of this blower is arranged perpendicular to the axis of the laser tube. After leaving the blower, the gas on both sides directly flows into a broad channel which includes the cooler, and is then deflected into the ends of the laser tube. The blower wheel is made of titanium and has a speed of 42,000 rpm; it revolves a gas volume of more than 2.5 $m^3/s$. A folded system of two parallel laser tubes with a 42-mm diameter is used. This laser now produces 2-kW output.

It is remarkable how compact both the transverse and longitudinal lasers are; they have a volume of only 0.25 $m^3$ (not counting the power supply). The longitudinal laser is less than 2-m long.

Current experiments assess the relative merits of the two designs, and when a final decision is made, it is expected that 5 kW will be achievable.

Needless to say, apart from laser development, Battelle is also in the forefront of laser applications (optoelectronic communications, laser spectroscopy, laser chemistry, isotope separation, laser scanning microscopy, particle and fiber analysis, material preparation and modification, remote sensing and chemical analysis, etc.). But it would lead too far to discuss examples here.

## Microscopic Aspects of Nonlinear Optics

Pioneering research is done at the Physics Faculty of Frankfurt University in the area of semiconductors and the electrical and optical phenomena related to such systems. Deep theoretical studies, experimental research, and some practical applications are all covered. The work is done by a close cooperation of several departments, primarily the Institute for Physics (Professor C. Klingshirn's group) and the Institute

for Theoretical Physics (in the unit headed by Professor H. Haug). The following is a brief summary of the general research framework.

Background. The groups are interested in the phenomena that occur in highly excited semiconductors. The microscopic theory of these processes is important because they determine the nonlinear optical properties of the materials, which manifest themselves in the intensity dependence of absorption, dispersion, and self-amplification of light, as well as more involved behaviors such as optical bistability. The experimental work is done, of course, by using short pulses of high-power laser light, and the institute is well equipped with modern excimer and dye lasers as well as with advanced optical multichannel analyzers.

In a semiconductor the absorption of a photon with appropriate energy will cause an electron to move from one filled level in the valence band to an empty level in the conduction band. Thus an electron-hole pair (e-h) is created. The optical properties of a semiconductor are determined by the e-h interaction. If the excitation energy is small so that the concentration of e-h pairs is low, one must consider only the attractive Coulomb interaction and the interaction of single e-h pairs with phonons and impurities. But at higher intensities, one generates such a dense e-h pair population that the dominant interactions are those between the electronic excitations. Consequently, the explanation of the nonlinear optical properties of semiconductors (which are observed at these high intensities) must take into account many-body effects which arise due to the long-range Coulomb interaction in the quantum mechanical many-body system of electrons and holes.

At relatively low densities, bound e-h pairs are formed which are called excitons. At high temperatures they get ionized into electrons and holes, but at low temperatures one can observe also bound states of two excitons, i.e., excitonic molecules. Furthermore, in many direct-gap semiconductors the band-to-band transition is dipole-allowed, so that there will be a very strong interaction between photons and some exciton states. As a consequence, quasiparticles "consisting" of excitons and the electromagnetic field will be created. These are called excitonic polaritons. It is not difficult to show that the real and imaginary part of the dispersion of excitonic polaritons (i.e., of the momentum dependence of the energy) determine the corresponding parts of the complex refractive index, hence the index of refraction and the coefficient of absorption.

Now, if we go to higher excitation intensities where the interparticle spacing becomes comparable to the Bohr radius of the exciton, the screening of the e-h potential is so strong that the bound state becomes unstable. In many semiconductors at low temperatures one then observes a first-order phase transition from the exciton gas to a degenerate e-h plasma liquid. But if the lifetime of the e-h pairs is short to start with, the phase separation cannot develop, and the phase transition becomes continuous. In practice, all sorts of combined situations can occur. The phenomenon of optical bistability is an example of first-order nonequilibrium phase transitions. This is observed as a sudden change of intensity in the light transmitted through a Fabry-Perot interferometer filled with an optically nonlinear medium. (The "optical length" of the cavity changes if the index of refraction changes. This type of optical bistability is therefore called dispersive.)

It is against the above-sketched theoretical background that the work of the Frankfurt group (consisting of nearly 30 people and sponsored by the Deutsche Forschungsgemeinschaft and by the European Joint Project on Optical Bistability, must be reviewed (see page 283 of this issue). We give only a few representative examples of very recent studies.

New Studies in Plasma-Induced Nonlinearities. Klingshirn and associates have studied plasma-induced optical nonlinearities by using a CdS sample and an intense laser beam in the spectral region close to the absorption edge, and also at the position of the pump laser frequency. (These nonlinearities are the variation of optical properties caused by the transition from a low-density exciton gas to an e-h plasma.) The researchers determined transmission, absorption, and refraction spectra. In a related, very sophisticated experiment they showed that the nonlinearities at the photon energy of the incident laser may lead not only to dispersive but also to absorptive optical bistability. This is a new phenomenon. The mechanism of induced absorption causes intensity-dependent nonlinear changes of the optical properties which lead to bistability. The remarkable feature of absorptive bistability is that, unlike dispersive bistability, no resonator geometry is needed. The Frankfurt group is a leading authority in this field. Haug and his colleagues presented a detailed theory of the effect. He

calculated the intensity-dependent absorption coefficient microscopically by taking into account band gap renormalization and band filling due to formation of an e-h plasma.

Further experimental studies of the e-h plasma in CdS by Drs. Klingshirn and K. Kempf, used a two-beam method for gain, and reflection spectroscopy and a new technique which allowed a spatial and temporal resolution of 5 μm and 2 ns respectively. They investigated the optical gain, reflection, and spatial extension of the e-h plasma under stationary excitation conditions. The novelty relative to similar studies by other groups was that the experiments in the past were done on CuCl (rather than on the important II-VI materials) and that the less sensitive method of luminescence was used.

A very amusing study by Klingshirn and coworkers (including Dr. V.G. Lyssenko from the USSR) demonstrated diffraction from laser-induced gratings in CdS at low temperatures, in the spectral region of the absorption edge. The cause for the formation of a grating is the broadening of the excitonic absorption band, a new resonance due to two-polariton transitions to a bi-exciton, and the formation of an e-h plasma with increasing excitation intensities. The importance of the work is that it demonstrated the feasibility of using the laser-induced grating technique for the detection and interpretation of excitation-induced optical nonlinearities in the spectral region of the excitonic resonances. Furthermore, they showed that some of the nonlinearities yield a dispersive or an absorptive optical bistability.

Drs. S. Schmitt-Rink and C. Ell in Haug's group are studying excitons and the e-h plasma in quasi-two-dimensional systems. Such systems are interesting because, due to the strong enhancement of their binding energy under quantum confinement, excitons can be observed in them even at room temperature. Experimentally such systems are best realized by thin semiconductor films or in thin semiconductor quantum wells with a very large barrier thickness and height. The authors have calculated the renormalized single-particle energies and the exciton binding energy as functions of the carrier density and the temperature. They also discussed nonlinear optical susceptibility. Quasi-two-dimensional systems are exciting because they may lead to a breakthrough in integrated optics.

Conclusion

After my less than 2-day visit to Frankfurt I felt that the time was well spent: despite of the variety of topics that I found valuable to report on, there is a striking unity of the effort, done in several groups, that surely deserves strengthening, by appropriate mechanisms, interactions between the US Navy research community and our colleagues on the embankments of the Main.

*12/12/84*

## NONLINEAR AND UNSTABLE SYSTEMS: SYNERGETICS IS FOCUS AT TUBINGEN

*by Paul Roman.*

Many institutes of information sciences have emerged in the past two decades, with a variety of interests and profiles. The Institut für Informationsverarbeitung at the University of Tübingen, West Germany, is rather unusual.

Its director, Professor W. Güttinger, spent a distinguished career in theoretical physics (primarily in quantum field theory) in Munich before he realized his vision of a truly multidisciplinary institution of internationally conducted research and teaching that would define "information" and "information processing" in a very broad sense. He defines information as any organized, *generic* knowledge about physical (or biological) systems and information processing as the application of *general* methods that allow us to correlate, decode, and codify pieces of information in a manner which reveals the underlying structure. This view of information science led to a flexible institute which has activities that cover a large area of the natural sciences and which also has the framework for addressing non-computational and system-theoretic aspects of data processing.

Currently the institute has two major research groups. The one focusing on information technology proper and discrete systems concentrates on the design and implementation of fault-tolerant distributed computer systems. (Fault tolerance means the ability to correctly carry out algorithms, independently of hardware defects and software errors.) Fault-tolerant algorithms and robust data structures are also developed and analyzed. The group is headed by Professor M. Dal Cin and has external support both from the Deutsche Forschungsgemeinschaft and the Volkswagen Foundation. The second, larger

research group--called System Theory and Synergetics, about which I will report in some detail--is headed by Güttinger himself, has about 12 researchers, enjoys Volkswagen support, and has strong ties with several British as well American universities, particularly the University of Wyoming and the University of Denver. (A third group, on information processing in the nervous system, which cooperated closely with the local Max Planck Institute for biological cybernetics, became inactive as the result of the tragic accidental death of its leader and fiscal retrenchment at the university.)

## System Theory

It is not easy to characterize properly the multifaceted, vigorous, and very enthusiastic work done by the System Theory and Synergetics group. The leading principle chosen is the concept of system stability, which is taken as the basis for a generalization of Thom's program, attempting a unified theory of structure formation and structure recognition in physical systems with analogous critical behavior. As is well known by many research groups in this area, a possible basis for this type of inquiry is "catastrophe theory," which is a picturesque name for topological investigations regarding bifurcations and singularities in nonlinear systems. The main thrust of work can be characterized as a general geometrical approach to "synergetic" (that is, system theoretic) phenomena and applications.

## Structure Formation

In the subarea of structure formation investigations, the starting point is the observation that stable systems preserve their qualitative features under small perturbations or deformations. Consequently, universal critical phenomena possess a common geometric origin and can be classified by means of topological normal forms. These give rise to branching phenomena (called bifurcations) which describe globally the formation of spatially and temporally varying structures. They also explain the spontaneous state changes that occur in nonlinear dynamical systems when under the influence of competing forces or control variables that, because of conflicts, induce instabilities. It is interesting to realize that symmetry breaking (caused by fluctuations or external influences) enables a system to take cognizance of its environment and adjust to it by going through spontaneous state changes which lead eventually to stable formations as observed in nature. This viewpoint, not entirely new but systematically and consistently pursued in Tübingen, permits a unified theory of self-organizing systems with analogous critical behavior. Newer studies in this area are done (or are planned) in optical multistability, plasma phenomena, and spatially and temporally coupled bifurcations, and will be applied to areas as dissimilar as turbulence, solitons, elementary particles, and even cosmology.

## Recognition of Structures

The second subarea of research concerns the recognition of structures. The Tübingen group always strongly emphasized that the same bifurcations and singularities that are the basis of structure formation also determine the inverse problem of structure recognition and imaging of unknown systems, patterns, and structures when these are probed by scattering of wavefields or ray families. Güttinger explains this by pointing out that to allow the reconstruction of an object and its structure from observing the scattered waves, the scattering process must be insensitive to small perturbations--i.e., it must have structural stability. In other words, the geometries underlying pattern formation and pattern recognition are both subject to the generic principle of structural stability, so structure formation and structure recognition are just two sides of the same topological coin. Pioneering research of the group in this field already has led to significant technical progress in the remote sensing of three-dimensional structures. So far, interesting results have been found regarding the reconstruction of layered media from seismograms, radio echoes, and other geophysical or material-science scattering data, and the classification of ruptures, dislocations, and imperfections with nondestructive testing. Current work addresses imaging in turbulent media, [illegible] wavefields, ultrasound tomography, polarization effects in radar meteorology, and ocean acoustics.

It may be interesting to note that even though most of the System Theory and Synergetics group's work is highly abstract and is done like all work in a department of theoretical physics would be done (i.e., by paper, pencil and sleepless nights), the group also uses with pleasure and excitement a symbolic manipulation software (California Institute of Technology's SMP, marketed by Inference). So far the researchers have developed an interactive program in which they feed in differential equations and automatically get bifurcation diagrams for a large class of equations.

An updated version will be used in the future to do detailed bifurcation-theory computations which, some people feel, just cannot be done "slowly."

Work Relevant to the US Navy

Two particular research results of the group represent a good sample of the current style in Tübingen and may be of special interest to readers in the Navy labs.

Optical Bistability and Self-Pulsing. This research, carried out primarily by Dr. D. Armbruster, addresses the problem within the framework of imperfect bifurcation theory. It is shown that the joint appearance of a hysteresis cycle in the CW-transmission curve and of transitions to self-pulsing can be described as an interaction between steady-state and Hopf-type bifurcations, induced by varying the incident field intensity. The normal form which determines the bifurcation equations for the most degenerate case is a corank two and codimension four polynomial, which can be extracted from partly analytic, partly numerical studies of the Maxwell-Bloch equations. The structurally stable unfolded bifurcation diagrams have been analyzed and, besides describing correctly and fully all observed bifurcations to self-pulsing, they also predict a number of new generic transitions. For example, transitions leading to the formation of "islands" with self-pulsing behavior are demonstrated. Also, the formation of two very close hysteresis loops between self-pulsing and CW-regimes is deduced, and this is the first instance of a periodic solution branch that is not stably connected to a stationary solution in optical bistability. Finally, it has been shown that several routes to chaotic behavior, not characterized by frequency doubling, should be open for such systems.

Topological Approach to Inverse Scattering in Remote Sensing. This work, a cooperation between Drs. W. Güttinger, G. Dangelmayr, D. Armbruster, and F.S. Wright, analyzes the topological problem that underlies inverse scattering by determining the caustic singularities impressed by an unknown surface on a sensing wavefield. Since the inversion process must be qualitatively insensitive to slight perturbations, it follows that the dominant singularities which generally occur in recorded signals, travel-time curves, surface-contour maps, and Fresnel-zone topographies, as well as the associated diffraction pat- terns, can be classified into a very few topological normal forms described by catastrophe polynomials. As the relative source-receiver positions vary, the observed patterns change their morphologies according to universal bifurcation sets. Thus, one is led to a new, essentially geometric processing methodology for surface reconstruction. Incorporating the above-described topological concepts into S-matrix techniques of inversion theory offers new and practical tools for all routinely used sensing processes, with applications varying from ocean acoustics to phonon spectroscopy. Current practical research is strongest in seismologic applications. Actually, it is rumored that the whole motivation to do work in this area of remote sensing came when someone casually inspecting a seismogram suddenly realized that it was strikingly similar to a catastrophe diagram.

*12/12/84*

## OPTOACCOUSTICS AND ADVANCED MICROELECTRONICS AT THE BUNDESWEHR UNIVERSITY, MUNICH

*by Paul Roman.*

High-quality research in optoacoustics and microelectronics is being done at a military school that is not well known in the US--the Bundeswehr University near Munich.

Background

The Hochschule der Bundeswehr, located on an expansive modern campus at Neubiberg, is the larger of the two military universities in West Germany. It went into full operation less than 8 years ago. All its undergraduates are future officers in training whose work will be in various areas of science or engineering; but the curriculum is very broad and covers also specializations in the social sciences and education. The many graduate students, working up to PhD degrees, are not, in general, associated with the armed forces and come from a large number of countries, ever from non-Allied nations.

The Institute of Physics, which I visited, is administratively within the Faculty of Electrotechnics, which to a large extent determines its research profile. Within the institute I found two areas in which very high quality and innovative work is done: (1) optically generated thermal waves and optoacoustic (or photoacoustic) detection/regulation (conducted by Dr. G. Busse and associates in the electro-optics/laser division run by Professor B. Bullemer); and

(2) microelectronics device fabrication and theoretical studies of metal oxide semiconductor (MOS) and superlattice devices (conducted by Professor I. Eisele and associates in the same group, and Dr. J. Becker, respectively).

Optoacoustics and Related Areas

The idea to use thermal waves for material probing goes back to Angstrom, who in 1863 produced periodical changes of temperature by alternately applying hot steam and cold water to one end of a metal bar and, with thermometers along the bar, observed the occurrence of maxima and minima. From the phase difference measured with two thermometers at a certain distance apart, he determined the thermal diffusion coefficient of the sample. Subsequently, the optoacoustic effect was discovered by Bell in 1880, but it took nearly a century to realize that this effect can be only interpreted in terms of thermal waves. ("Optoacoustic effect" simply means the generation of acoustic waves in a medium due to the absorption of light energy.) In the 1970s, photoacoustic spectroscopy was developed successfully. But Busse raised a slightly different question: could one use optical generation of thermal waves for detailed study of structures within materials, both metallic and plastic? The answer is positive, for a number of reasons. First, modern lasers provide excellent thermal wave sources with variable geometry (including a point source) and a wide range of modulation frequencies. Second, optical remote energy deposition removes all problems of thermal contact. Third, the sensitivity of thermal wave detection has improved to very high values.

Although in his earlier work Busse used nonscanning inspection methods (for example, to measure remotely the thickness of a 50-μm coating on an 0.5-mm metal substrate with a resolution of 0.5 μm), his current efforts are in the area of scanned material inspection. Here, one is interested in correlating local changes of the thermal wave signal with known structures; and, of course, the ultimate goal is to use the observed signals for the characterization of unknown structures.

Magnitude or phase of the signal is monitored as a function of coordinates. One may scan either along one coordinate only or scan in a raster fashion across an area. In the latter case, one makes a map of the locally obtained signal, which can be considered to be an image.

The basic experimental setup is sketched in Figure 1. In most experiments a CW-operated $CO_2$ laser or an $Ar^+$ laser (from 15-mW to 10-W output) was

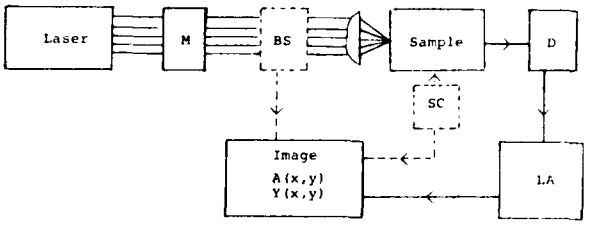


Figure 1. Experimental setup.

used. The mechanical or electro-optic modulator, M, acts as a beamchopper, operating up to 10-MHz rate.

The box BS symbolizes a beam scan mechanism (using rotable mirrors), and SC is a sample scan mechanical device; these two scanning mechanisms were used alternately in different types of experiments. The thermal wave generated at the focal point in the sample is detected in D, which is either a microphone or a piezoceramics device (i.e., optoacoustic sensor) directly coupled to the sample; or it may be an infrared detector (photothermal device) that detects the thermal wave signal as infrared radiation remotely. (If the latter is used, one can put it either into the transmitted or into the reflected thermal wave path.) The scan electronics provides information on the x, y coordinates where the signal was obtained. This is combined with the detector's output that is first passed through the lock-in amplifier, LA. The receiver unit then shows the collected data A(x,y) or $\phi(x,y)$ and allows for inspection and evaluation of the results. For example, an x-y recorder can be used to show a projection of the three-dimensional signal surface, or an oscilloscope image can be obtained in the form of a perspective line drawing, a halftone image, or a combination of both. Figure 2 is a reproduction of the magnitude image (left) and the phase-angle image (right) of a green leaf at 167 kHz. Figure 3 shows the magnitude and phase photothermal rear surface image of welded stainless steel. On the left a simultaneously recorded optical image is shown for comparison. (This can be obtained by putting a beam splitter between M and BS and using a telescope.)

Busse is quick to point out that his methodology for nondestructive material testing is still in its infancy and that the experimental equipment is neither compact nor cheap. But he is confident that the potential applications, such as inspection of metals and semiconductors, and analysis of layers and biological samples will justify further exploratory work.

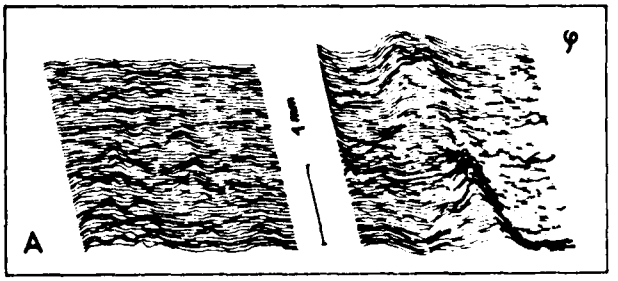


Figure 2. Magnitude image (left) and phase-angle image (right) of a green leaf.

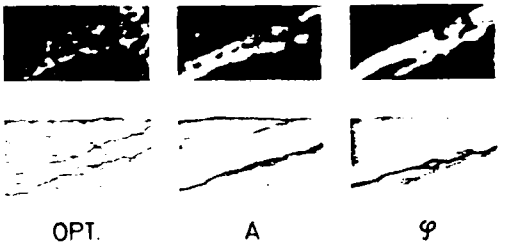


Figure 3. Magnitude and phase photothermal rear surface image of welded stainless steel.

Having gained experience with optoacoustic techniques, Busse in the early 1980s initiated a new research area in which he employs the optoacoustic effect for the development and stabilization of far-infrared (FIR) lasers. As is well known, high-level rotational band transitions in simple organic molecules allow for construction of waveguide lasers that can operate tunably in the range from 30 μm to 2 mm. An efficient way to drive such lasers is optical pumping by another, CW-operated, laser such as a $CO_2$ laser. However, for the operation of such optically pumped FIR lasers the pumping laser must first be set to an emission line which is near the absorption line of the gas to be pumped. Second, to get efficient operation, the pumping laser must be tuned within the molecular transition to find the optimum pump frequency at which the largest number of optically excited molecules is obtained. Busse and his colleagues used the optoacoustic effect to solve both problems by monitoring the number of optically excited molecules in the FIR laser. They simply coupled a microphone to the gas in the FIR laser resonator and chopped the radiation of the pumping laser. When this radiation is absorbed by the gas, periodic pressure changes occur due to the optoacoustic effect, and the resulting acoustic signal can be detected by a microphone, so that its signal indicates optical pumping. The microphone was directly connected to the FIR laser cavity rather than inserted into a separate gas cell because this arrangement has the advantage that the signal can be used also to find the geometrical adjustment at which the pump beam is best fed through the coupling hole into the cavity.

Busse's researchers verified the operation of this arrangement using $CH_3F$ and $CH_3OH$ filled FIR lasers, and showed clearly that one can find the optimum pump frequency independently of FIR laser action by just monitoring the acoustic signal. In later experiments they used the microphone as a sensing element in a feedback circuit which stabilizes the $CO_2$ laser frequency to the optimum pump frequency for FIR laser action. With such techniques they obtained stable operation for a surprisingly large number of wavelengths, with good output. (For example, with methanol they achieved sustained 100-mW power at 100 μm.) They are now using the technique to search for new FIR laser lines in a variety of materials, such as in $CH_3CHF_2$ or methanol isotopes, and to develop efficient FIR lasers.

## Microelectronics Research

The increasingly large scale integration of electronic devices and systems reveals the decisive importance of effects (such as hot electrons, ballistic charge transport, superlatices, quantum effects) which so far have not played an important role. Further progress therefore requires both the development of new technologies and the theoretical study of novel ideas based on new basic phenomena. Both these concerns are addressed in the research group under Eisele's direction.

Silicon Epitaxy in High Vacuum. Molecular beam epitaxy (MBE) is a relatively new methodology and has been used so far mainly for GaAs preparations, despite the fact the MBE applied in silicon technology allows for an arbitrarily structured doping of the epitaxy layer ("buried doping"). But because of the high inertia of thermal evaporation cells, it was not possible until recently to achieve arbitrary doping profiles. This difficulty has been successfully attacked and handled by Eisele and his coworkers. The particle flux from an effusion cell at a distance r from the center of the source orifice with an area A is given by

$$F = C\, p(T)\, A/r^2\, T^{\frac{1}{2}} \text{ atoms/cm}^2\text{ s},$$

where p(T) is the vapor pressure of the evaporating material and C a known constant. The pressure can be approximated by the Clausius-Clapeyron equation, $p(T) \sim \exp(-\Delta H/RT)$. In customary evaporation cells, the flux control is achieved by varying the temperature. However, the switching between two thermal equilibrium states strongly depends on the thermal resistance of the effusion cell; and to achieve only very small thermal fluctuations, the thermal resistance should be made large. Therefore, typical time constants between 10 to 60 seconds arise, and these limit seriously the control of evaporation profiles. Eisele observed the almost obvious: instead of varying the temperature, the source orifice area A should be varied. This can be achieved with a time constant less than 1 second. He devised a mechanical shutter control in which a movable shutter is guided between two fixed plates, each of them containing an identical slit of $2 \times 5$ mm$^2$. Pushing or pulling the movable shutter results in a minutely and rapidly controlled variation of the area for the emerging particle flux. It was shown that the cell is highly stable. Furthermore, using the output of a built-in mass spectrometer and other monitoring devices in a feedback loop, a microcomputer was wired up to control the effusion cell. With this advanced design it became possible to combine shutter and thermal control of the evaporation rate to always have a maximum controlling range. The less than 2-second time scale variability of the evaporation rate now allows the researchers to achieve arbitrary doping profiles: the profile of the shutter control translates exactly into the doping profile of the epitaxial layer. Thus, it becomes possible to perform easily and in one operation procedures that previously needed several implantations and the deposition of interposed epitaxial layers.

Quantum Theory and Shift Registers. Dr. J. Becker in Eisele's department is concerned, as a long-term project, with solving theoretical problems of devices relevant to parallel processing. His focus is on the need for local memories, especially dynamic memory cells. When dynamic cells are arranged as shift registers, they need very little space because by shifting the data around they replace most connections needed otherwise by shifting the data around.

The best known type of dynamic shift registers is a charge-coupled device (CCD), in which information is represented by a charge package, stored in a little capacitor. Probably the best way to construct a CCD is to use MOS technology, and since MOS devices play an increasing role in many fields, Becker concentrated efforts on improving the understanding of MOS structures. He points out that because of the spatial scale of the energy level structure through the metal-oxide/insulator/semiconductor layers in the presence of a bias field, it is an absolute necessity to describe charge transport (current) in the z-direction (vertically to the surface) by quantum theory. Actually, the Schrödinger equation (supplying the charge density via $|\Psi(z)|^2$) must be solved together with the Poisson equation in a self-consistent manner. The Poisson equation must include the density of electrons, holes, and ionization donors and acceptors. The complicated motion of charge carriers requires the application of the Boltzmann equation, including the term that contains the spatial variation of the diffusion constant. (In other devices, this term can be neglected.) Finally, Becker points out that the electrons are not in thermal equilibrium with the lattice, and this must be also taken into consideration. The resulting differential equations for the current are very complicated. But approximations, valid under specialized conditions, can be easily obtained by computer calculations. The results so far obtained show an extremely good match with measured characteristics. These studies, therefore, should facilitate the building of better MOS technologies.

Becker believes that novel "superlattice shift registers" could become very effective storage devices in three-dimensional, very large scale integrated systems to come. Superlattices are monocrystalline samples with an additional periodic structure that typically has a period of 50 to 100 angstroms. So far only one-dimensional superlattices have been made, with the superstructure in the direction of epitaxial growth (the z direction). There are two ways of making a superlattice: either by alternating deposition of different materials (such as GaAs and GaAlAs) which have a similar lattice constant (hetero-superlattices), or by a periodic variation in the doping concentration (doping superlatices). In both cases the upper edge of the valence band and the lower edge of the conduction band become modulated with the period of the superlattice. Doping superlattices have an interesting property: there is a spatial separation of electrons and holes which results in an enormously enhanced lifetime of the charge carriers and hence of nonequilibrium states.

If the valleys in the modulation of the band edges are sufficiently narrow and deep, quantized levels will appear, and methods are now available to calculate these levels, at least via self-consistent methods. It turns out that the low-lying energy levels of the states in the superlattice valleys have virtually no z-direction momentum dependence--i.e., no level widths--which means that the electrons are very well localized in the individual valleys. Electrons occupying the higher states can tunnel through the superlattice more easily, so these levels show some $k_z$ dependence, and are called minibands. The density of states is constant between the minibands and changes rapidly with them.

From this description it follows that superlattices are natural structures (like MOS devices) to store charge packages. If this fact is to be used for constructing shift registers, a method must be found to shift the charge packages. Since it is unlikely that it will be possible to make gates for switching individual layers of the superlattice, Becker proposes an unusual and surprising solution. This would be a mechanism that combines resonant tunneling between neighboring valleys and thermal relaxation in the valleys in a two-phase ("sample" and "hold") step, which is controlled by voltages applied externally to the whole superlattice shift register. The idea can be schematically represented as follows. One cell of the shift register consists of two adjacent valleys that are not identical, each of which contains two quantum levels (Figure 4). The upper levels are thermally broadened, with tails into the hills, whereas the lower levels are well localized sharp states. The left valley is used for temporary storage in the sample step, and the right valley will later contain the charge in the hold step. In the sample step an electric field is applied so that level $D_n$ of the nth cell is in resonance with level $A_{n+1}$, as shown in Figure 5. If $D_n$ contains a charge package, it will tunnel to level $A_{n+1}$ and thermalize into level $B_{n+1}$, which is mestastable. In the hold step, the external field is changed so that

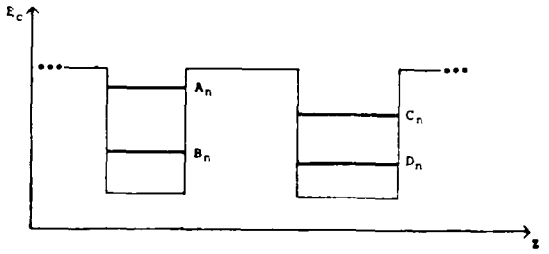


Figure 4. Cells of shift register.

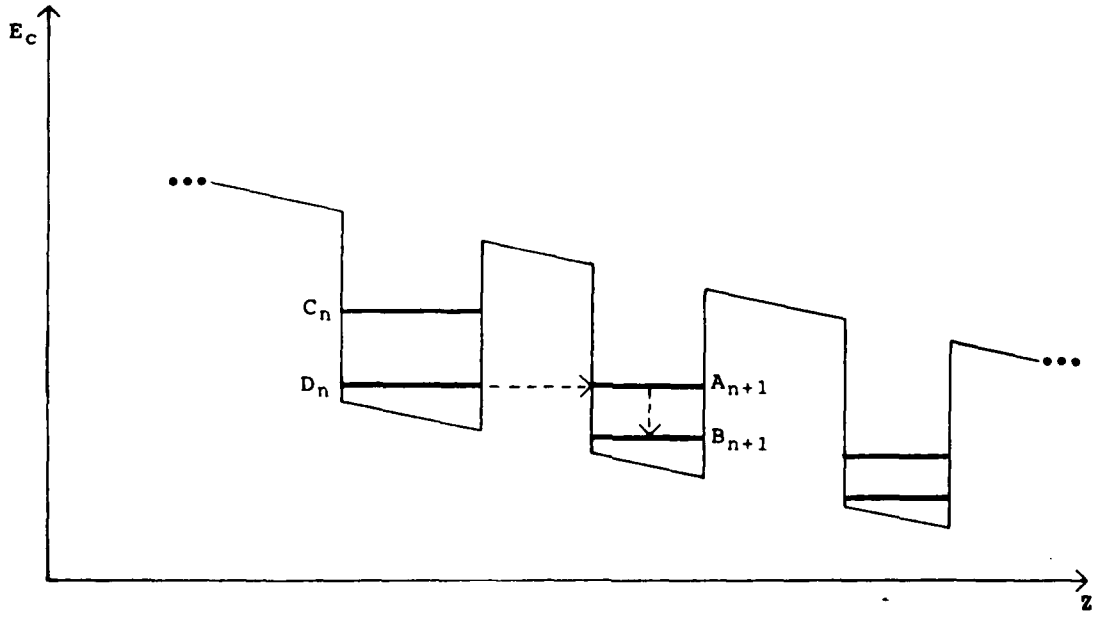


Figure 5. Sample step.

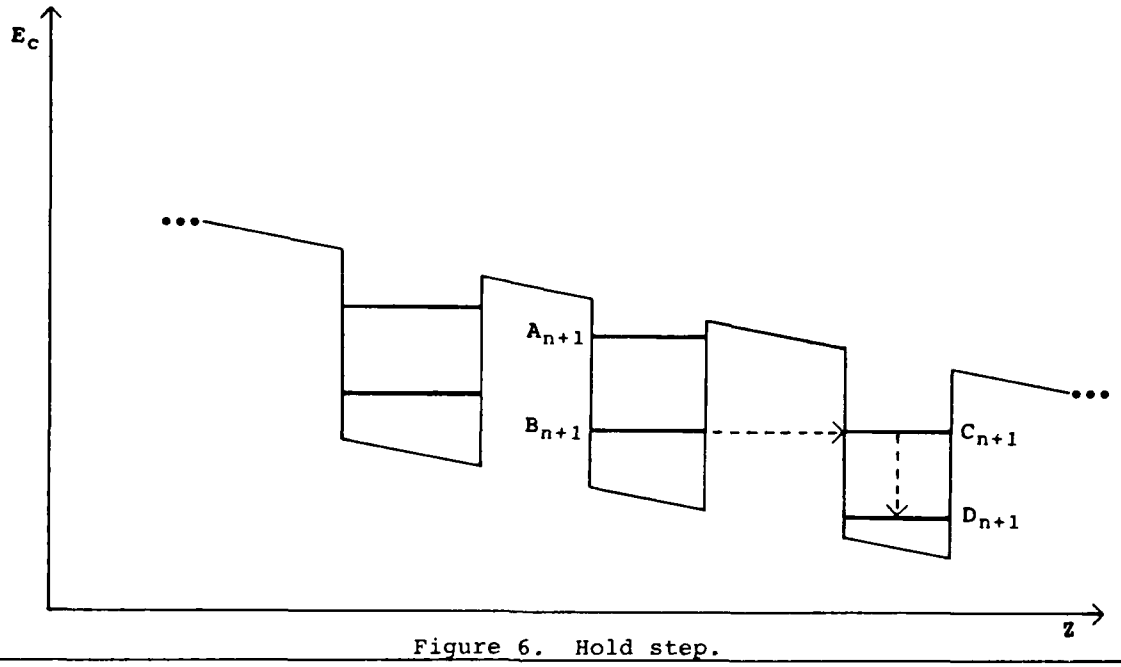


Figure 6. Hold step.

the levels $B_{n+1}$ and $C_{n+1}$ are in resonance. If $B_{n+1}$ contains a charge package, it will tunnel into $C_{n+1}$ and then thermalize into $D_{n+1}$ (Figure 6).

Registers based on this principle would consist of towers grown on a wafer with an area of 5×5 $\mu m^2$ and a height of 8 μm, and would contain 100 cells of a height of 800 angstroms each. The doping concentrations would be $3\times10^{18}$ $cm^{-3}$. Such devices could be fabricated by modern MBE technology (as discussed above). Detailed calculations show that efficient operation with characteristics desired by designers of future dynamic memories can be achieved without difficulty. Of course, there are quite a number of questions left open now--both physical problems (such as the influence of donor levels, impurity- and phonon-scattering) and technical problems (traps, limited lifetime of tunneling barriers). Nevertheless, these exciting ideas deserve watching.

*12/12/84*

# Space Sciences

## THE NEW ASTRONOMY IN THE UK: NEW TECHNOLOGY, NEW TECHNIQUES, AND NEW FACILITIES

*by Norman F. Ness. Dr. Ness is the Liaison Scientist for Space Physics in Europe and the Middle East for the Office of Naval Research's London Branch Office. He is on reassignment until June 1985 from Goddard Space Flight Center, NASA, where he is Chief, Laboratory for Extraterrestrial Physics.*

The latest node in the UK's Starlink computer network was dedicated by Sir Bernard Lovell in February at Leicester University. Starlink is sponsored by the Science Engineering Research Council (SERC) and is primarily intended for the use of astronomers, emphasizing the interactive processing mode in the analysis of observational data.

### The Starlink Network

The hardware is a network of VAX 11/750 and 780 computers communicating with each other via dedicated telecommunication lines in a star network centered at Rutherford Appleton Laboratory, Chilton. The 780 systems typically have a 4-megabit memory, 1K-megabit disk, and two tape systems, and are located at Cambridge University; University College, London; Jodrell Bank Observatory; the Royal Greenwich Observatory at Herstmonceaux; the Royal Greenwich Observatory at Edinburgh; and the Rutherford Appleton Laboratory. The 750 systems typically have a 2-megabite memory, 1/2K-megabite disk, and one tape transport, and are located at Birmingham, Durham, Leicester, and Manchester universities.

Each node includes one or two identical image-display systems, the Advanced Raster Graphics System by Sigma Electronics, which allows a display of color images up to a raster size of 512×512. All the usual functions necessary for modern-day processing of images are available on this system. Other users not located at nodes of the network are able to use Starlink in various ways, depending upon the specifics of their hardware and proximity to a node. One of the primary purposes of the system is to encourage, both philosophically and by ease of implementation, the exchange of software appropriate for analysis of various astronomical problems. It is Starlink's policy to make available, at every node, all software which is developed on the system so as to maximize the commonality of the various research groups' efforts. Starlink has implemented a software environment in which all applications software can be integrated and will enable any astronomer on any interactive terminal to manipulate data and run various data-reduction programs efficiently. Most commonly needed image-handling and processing routines have been adapted from other systems and other machines.

Central management of the Starlink system is provided by the Rutherford Appleton Laboratory. A scientific advisory group is responsible for monitoring the overall progress of the project. The present project scientist is Dr. Gordon E. Bromage. There are seven special interest groups addressing various areas of astronomical research: spectroscopy, two-dimensional image processing, databases, the International Ultraviolet Explorer (IUE) database, the EXOSAT spacecraft, and the Infrared Astronomical Satellite (IRAS) database and radio astronomy.

Starlink is an SERC national facility, and as such there are no direct charges to any users at any of the nodes or remote terminals. Each node has a site manager who shares responsibility with the Chilton node for overall management of the project, providing systems software, providing and organizing the production of various astronomical applications software, supporting and educating users and programmers, providing astronomical direction to the project, and, finally, maintaining contact with interested groups elsewhere. The entire concept of Starlink is that it is to be a user-friendly system that will provide the research scientist with the necessary tools and algorithms to fully utilize the information and content of the data obtained from both ground-based and space-based telescopes.

Telescope Facilities

The UK has also completed, or has under construction, new telescope observing facilities at installations outside the UK. Indeed, one of these telescopes, the Isaac Newton telescope, was first installed in 1967 at the Royal Observatory at Herstmonceaux, but the poor observing conditions caused by both weather and light pollution associated with human activities precluded this telescope's realizing its technical goals. It was subsequently decided to move the 2.5-m facility to the Canary Islands, where it is now installed on the 8000-foot-high Roque De Los Muchachos mountain on Las Palmas. The William Herschel telescope, a 4.2-m instrument, is presently undergoing final trials; when completed, it will become the first telescope in the world which has been specifically designed for remote control from another continent.

The infrared telescope of the United Kingdom (UKIRT) has been installed on the volcanic peak of Moana Kea in Hawaii, which is at an elevation of 14,000 feet. Remote control of this, the Royal Edinburgh Observatory's IR telescope, is also achieved via telephone lines which link computer systems at either end. The use of new charge-coupled devices and other matrix detector systems in different wavelength regions automatically produce images which are computer compatible and eases the way in which both control and simultaneous monitoring of the results is possible.

One of the challenges in the future for the UK astronomy community will be the incorporation of Starlink into the remote control system of these new observatories. At present, Starlink can only provide access to the library of data collected from such observatories. Eventually, direct access to these telescopes by most of the astronomical community in Great Britain will be possible.

Remote observation and control of observatories and other facilities extend beyond the discipline of classical optical astronomy. In the area of radio astronomy, pioneered by the UK during the last 30 years, there are now five UK telescopes interconnected by a VAX 11/780 system at Jodrell Bank which permit operation as a multiple element interferometer. As in other areas of research, interferometry can improve the resolution and sensitivity of spatial regions studied so that astronomers can obtain more detailed data on the structure and dynamics of the many new objects recently discovered.

The UK has played a prominent role in space-borne measurements in

ultraviolet and IR astronomy with their participation in the IUE and IRAS international space projects of the US National Aeronautics and Space Administration. Because of the limit on funding throughout British science, it is expected that future facilities, either ground based, or space borne, will of necessity be constructed under the auspices of such international collaborations, either bilateral or multilateral. The new view of our universe created by these new facilities has already revolutionized our thoughts about its state and dynamical behavior. With these new computer-based facilities and networks, the traditional role of an astronomer is also being revolutionized by the possibilities of remote control and networked data processing and analyses.

*3/7/85*

# News and Notes

## THE EUROPEAN JOINT PROJECT ON OPTICAL BISTABILITY

The study of optical bistability (OB) is of considerable interest for several reasons. From the viewpoint of basic research, it allows the study of nonlinear dynamics of the electronic system of semiconductors and phase transitions far away from equilibrium states. It is also a good ground to study bifurcation phenomena and the passage to chaotic systems (see pages 271-276 of this issue).

From the side of applied research, it is important to realize that OB devices exhibit characteristics in the transmission or reflection of light that are analogous to those shown by electric components used in computers. Specifically, an optically bistable device may be considered an optical memory cell. Further, if it is constructed in a way that makes the hysteresis loop area small, it can be used in three different ways as a logic gate.

It is not surprising, therefore, that the European Economic Community (EEC) established a European Joint Project on Optical Bistability (EJOB). Current participants are: the Heriot-Watt University in Edinburgh, UK; the Max Planck Institute for Quantum Optics, Garching, the University of Frankfurt, and the Fraunhofer Institut at Freiburg, West Germany; the University of Milan and the University of Pisa, Italy; the University of Brussels, Belgium; and the University of Strasbourg, France. Projects, at this time, range from infrared tunable laser diode studies and InSb nonlinear semiconductors, through absorptive OB, to self-oscillation and chaotic solution studies. One of the goals is to develop, in the next 2 years, devices which will demonstrate the principles of an optical computer.

*Paul Roman*
*12/12/84*

## CRYSTAL-GAZING AT THE GENERAL ELECTRIC COMPANY, UK

Predicting technologies that may become crucial in fulfilling needs expected to arise 10 or more years from now is of great concern both to scientists in defense-related areas and to the industrial establishments eager to maintain and expand their leadership in high-technology areas. Apart from the high-risk nature of such an enterprise, economic considerations or manpower/resource limitations often prevent organized work in forward-looking science and technology.

I was very impressed to find out that one of the leading British electric/electronic companies, GEC, has invested heavily in organizing at its Hirst Research Center in Wembley a special department for long-range research. This unit, comprising about 30 people (about 3.5 percent of the total Hirst staff), carries out long-range "pre-research" (or "pre-information-assessment") into areas which may become important to the company on time scales much longer than those of programs with defined commercial objectives. The department covers all main areas of GEC activities (circuits and systems, devices, materials) without becoming superficial, and hands over promising possibilities for future basic research to the appropriate units of the center as soon as the feasibility is assessed. A particularly interesting feature of the long-range research project is that much of it is carried out in strong cooperation with universities, not only by the mechanism of substantial grants to either single departments or consortia and by direct student support, but also through seconding staff members to university research labs and through employing academics as resident visiting scientists.

I was very interested to learn what the leading GEC scientists regard as crucial "hot" research areas of the future and was told that, at the present time, the department has three focal areas:

1. Three-dimensional structures on the nanometer scale.
2. Molecular science in the field of creating and studying novel organic crystals with unusual electro-optical or other optical properties.
3. Mathematical theory of human visual perception and its computer (artificial intelligence) implementation.

3D Structures

The first area is surely promising and will be crucial, for example, in fifth generation information technology and communications; actually, many interesting results already have been achieved in a worldwide context (first experiences with superlattices and quantum well devices); so the Hirst guess about the importance of this area is perhaps rather obvious. Some specific topics they want to explore are:

- Growing of GaAs layers, 10-nm thick, by molecular-beam-epitaxy technology, with similar lateral dimensions (the latter achieved with electron- or ion-beam etching), obtaining in this way unusual superlattices.
- Using electron-phonon interaction methods for the exploration of surface properties in submicron devices.
- Optical defect identification.
- Quantum effects at ambient temperatures.

Since most of their work in these topics will be shared only with cooperating institutions, I may not have gotten the complete picture.

Organic Materials

In the second area, organic electro-optic materials, the researchers' main concern is the study of nanometer-thick films produced by the Langmuir-Blodgett (LB) technique. (The technique was first described by K.B. Blodgett, *Journal of the American Chemical Society*, Vol 56 [1934], 495.) It has been known for a long time that such films have a regular layer structure which is almost free of defects and whose thickness can be controlled with great precision. Thus, these films (which can be made from a wide variety of organic materials) can be compared to the superlattices of inorganic semiconductors, and LB techniques may be considered analogous to molecular beam epitaxy. There are both great promises as well as disappointments in this area, and the Hirst scientists are now studying homoepitaxy and in-plane anisotropy phenomena.

Human Vision

The emphasis given by the long-range research department to the third area, mathematics of human vision, perplexed me a bit, especially since they claim that their work is a far cry from widely studied theories of "computer vision." Apparently, their major concern at this moment is to achieve the reconstruction of three-dimensional information from two-dimensional input. The method is based on a sophisticated mathematical data reduction and optimization theory which uses items such as recognized edges and shapes in a sequence of visual two-dimensional images, by integration over a long sequence. The potential fruit of research in this area is that it may lead to imitating human visual perception by electronic means in quite distinct areas, including not only light-picture input but also radar, microwave, infrared, thermal imaging, sonar, and so on.

Conclusion

The initiative of the Hirst Research Center in "science futurology" deserves praise and should be followed with interest.

*Paul Roman*
*2/28/85*

## THE EUROPEAN SOCIETY FOR COGNITIVE PSYCHOLOGY: ANOTHER NEW FOCUS FOR ONRL LIAISON

ONR, London, is providing partial funding for the Inaugural Meeting of the European Society for Cognitive Psychology. The conference will be held in Nijmegen, The Netherlands, from 9 through 12 September 1985. The keynote address will be delivered by Professor Donald Broadbent of Oxford University, UK. Presentations have also been invited from 20 prominent cognitive psychologists from a range of European countries. The organizing committee for the conference and the society has been led by Dr. Alan Baddeley of the Medical Research Council-Applied Psychology Unit, Cambridge, UK, and by Professor Dr. J.A. Michon and Dr. J.L. Jackson-Roy of the University of Groningen, The Netherlands.

ONRL regards the creation of this society as an extremely important

event--not only because it will bring together and thus promote the best of European cognitive psychology, but also because it provides a focal point for communication between US and European scientists in this important field. ONRL's liaison function is substantially advanced by the existence of such focal points. It therefore has previously funded the formation of the European Association of Experimental Social Psychology, in 1962, and the European Association for Research on Learning and Instruction, in 1984. The first is now thriving; the second is off to a strong start. The European Association for Personality Psychology did not seek ONRL support for its founding in 1982, but its pattern was set on the social psychologists' model; it is also off to a strong start. It is hoped that the new society prospers as well.

*Richard E. Snow*
*3/7/85*

COGNITIVE PROCESSES AND SPATIAL ORIENTATION

A NATO Advanced Study Institute on Cognitive Processes and Spatial Orientation in Animals and Man will be held in Aix-en-Provence, France, from 27 June through 7 July 1985. The institute will present a multidisciplinary approach to the mechanisms of spatial orientation, examining such topics as spatial problem solving, cognitive maps, navigation and magnetoreception, neuroethology, cognitive versus sensorimotor encoding of spatial information, effects of cerebral lesions, and hippocampal, vestibular, and neostriatal functions in spatial orientation. Information and applications may be obtained from P. Ellen, Department of Psychology, Georgia State University, University Plaza, Atlanta, GA 30303, and from C. Thinus-Blanc, CNRS-INP9, 31 chemin Joseph-Aiguier, 13402 Marseille, Cedex 9, France.

*Richard E. Snow*
*3/15/85*

EUROPEAN CONFERENCE ON EYE-MOVEMENT RESEARCH

The Third European Conference on Eye Movements will be held from 24 through 27 September 1985 in Dourdan, France, near Paris. It is sponsored by the European Group for Eye-Movement Research, an informal network of over 125 scientists in Europe. Special topics for this Third Conference will be saccade programming, adaptability of the oculomotor system, visual scanning description and theory, eye movements in relation to lexicons and languages, and the usefulness of eye-movement studies in ergonomics. Organizers for the meeting are Drs. Ariane Levy-Schoen and Kevin O'Regan, Laboratoire de Psychologie Experimentale, 28 Rue Serpente, 75006 Paris, France; telephone 3266817.

*Richard E. Snow*
*3/12/85*

EUROPEAN JOURNAL OF PSYCHOLOGY OF EDUCATION

A new quarterly journal for the publication of original theory, research, and critical reviews in the psychology of education has been founded, with a first issue scheduled to appear in April 1986. The journal will publish articles representing the diversity of substantive interests in psychological research in education; no restrictions regarding kinds of subjects, topics, or educational contexts will be imposed. Editorial decisions regarding submitted manuscripts will be guided by the quality of theoretical reasoning and methodology represented, with a preference for experimental, differential, and developmental methods of investigation. In addition to the 25 to 30 articles expected for each volume, special issues on selected topics are also planned. Articles will be accepted in either English or French, with abstracts in the second language. The journal will be published by the Instituto Superior de Psicologia Aplicada in Lisbon, Portugal. Editorial and secretarial offices are at the University of Provence, France. Write to Professor Michel Gilly, UER de Psychologie, Université de Provence, 29 Ave. Robert Schuman, 13621 Aix-en-Provence, France.

*Richard E. Snow*
*3/12/85*

*BEHAVIOUR AND INFORMATION TECHNOLOGY*: A JOURNAL

An international quarterly journal on the human aspects of information

technology, titled *Behaviour and Information Technology*, is published by Taylor & Francis, Ltd., of London and Philadelphia. The journal concerns the convergence of three distinct industries--computing, telecommunications, and office systems--and the human aspects of design and use of equipment in and from these industries. It provides a forum for reporting both basic and applied research bearing on usability, acceptability, and the realization of the potentials of new technologies.

Free sample copies are available. Subscriptions can be placed with the following addresses: in the US, Canada, and Mexico, Taylor & Francis Inc., 242 Cherry Street, Philadelphia, PA 19106-1906; in the UK and its other territories, Taylor & Francis Ltd., Rankine Road, Basingstoke, Hants RG24 0PR; in India, UBS Ltd., 117/H-1 294B Model Town, Pandu Nagar, Kanpur 208 025; in Japan, Kinokuniya Company Ltd., Odakyu West-Shinjuku Bldg, 47-1 Hatsudai 1-Chome, Shibuya-Ku, Tokyo 151.

*Richard E. Snow*
*3/25/85*

## SPRINGER TO PUBLISH *MANUSCRIPTA GEODAETICA*

Springer-Verlag has announced that it will start publishing the journal *Manuscripta Geodaetica*, beginning with volume 10.

*Manuscripta Geodaetica* will publish papers on theoretical geodesy, processing techniques of geodetic data, and numerical results, with special emphasis on physical and mathematical geodesy. Moreover, mathematical aspects of geodynamics and space techniques will be considered, with interest focused on novel and computer-oriented procedures. Substantial space will be devoted to the applications of modern statistics, of approximation theory, and of advanced potential theory.

*Manuscripta Geodaetica* will emphasize modern techniques of contemporary mathematics, physics, and statistics in geosciences for the benefit of high-precision geodesy, geodynamics, and geophysics. In view of the increasing interest and the practical and scientific impact of global geodesy and geodynamics, the journal will cover modern space techniques in depth.

The managing editor is G.W. Hein (Institute of Astronomical and Physical Geodesy, University FAF, Neubiberg, West [illegible]). The 13-member international editorial board is chaired by E. Groten (Institut für Physikalische Geodäsie, Technische Hochschule Darmstadt, West Germany).

To subscribe, write to Springer-Verlag, Journal Promotion Department, P.O. Box 105280, D-6900 Heidelberg, West Germany.

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*[illegible]*

## NEW JOURNAL ON BIOSENSORS

A new international journal entitled *Biosensors* is being published by Elsevier Applied Science Publishers, Crown House, Linton Road, Barking, Essex IG11 8JU, England. In the US and Canada, free specimen copies are available from: Journal Information Center, Elsevier Science Publishing Co. Inc., 52 Vanderbilt Avenue, New York, NY 10017.

This new international journal presents authoritative reviews on research, technology, and application of biosensors. The scope includes both sensors that employ biological molecules or systems in the sensing elements and other devices that sense parameters in biological processes. Thus, many types of measuring devices are covered, including enzymes, whole organisms, and immunoelectrodes (both amperometric and potentiometric); piezoelectric crystal detectors; novel chemical sensors; optoelectronic devices; specialist applications of mass spectrometry and nuclear magnetic resonance; and types based on field-effect transistors and those which utilize the principles of biological fuel cells.

Since the biosensor field is multidisciplinary, spanning fundamental and applied aspects of biochemistry, electrochemistry, and electrons, some articles will be of an introductory nature, directed particularly at life scientists who are showing increasing interest in biosensors but might be new to the field. Others will concern end-user requirements.

In addition to reviews, publication of original papers is encouraged. There is also a news section covering important developments in industry, notes on new patents, product reviews and details of government funding. There will be four issues per year.

The managing editors are: (1) I.J. Higgins and A.P.F. Turner, Biotechnology Centre, Cranfield Institute of Technology, Cranfield, Bedford, MK43 0AL UK;

(2) W.G. Potter, Biotechnology Directorate, Science and Engineering Research Council, Polaris House, North Star Avenue, Swindon SN2 1ET, UK. The editorial advisory board is international in scope: J. Janata, US; C.R. Lowe, UK; F. Scheller, West Germany; S. Suzuki, Japan; D. Thomas, France; and L.B. Wingard Jr., US.

*Claire E. Zomzely-Neurath*
*3/18/85*

## ONRL STAFF CHANGES

In March we welcomed two new staff members. CDR Edmon D. Hagee, USN, joined the Naval Applications Division; he specializes in surface weapons systems technology. Mr. Fran Weigle, Liaison Technologist for Underwater Systems, comes to us from the Naval Underwater Systems Center, New London. He is on assignment until September 1985.

## ONRL COSPONSORED CONFERENCES

ONR, London, can nominate two registration-free participants in the conferences it supports. Readers who are interested in attending a conference should write to the Scientific Director, ONRL, Box 39, FPO New York 09510.

Influence of Electric and Electromagnetic Fields on Biological Structures Symposium, Bologna, Italy, 24-29 June 1985.

Numerical Methods in Laminar and Turbulent Flow, University College of Swansea, Swansea, UK, 9-12 July 1985.

Inaugural Meeting of the European Society for Cognitive Psychology, Nijmegen, The Netherlands, 9-12 September 1985.

Technological Application of Bilayers, Vesicles, and Langmuir-Blodgett Films, Denerja, Spain, 25-29 November 1985.

* * *

## EUROPEAN VISITORS TO THE US SPONSORED BY ONR, LONDON

| Visitor | Areas of Interest | Organizations to be Visited | Want Information? Contact at ONRL |
|---|---|---|---|
| Professor Kenneth Easterling<br>University of Luleå<br>S-951 87 Luleå<br>Sweden | Metallurgy/Ceramics | ONRHQ<br>(18 July 1985)<br>DTNSRDC<br>(19 July 1985) | Kenneth Challenger |
| CDT Arnold Böhrer<br>Rekruterings on Selectiecentrum<br>Sectie Psychologisch Onderzoek<br>Kazerne Klein Kasteeltje<br>9de Linielaan<br>1000 Brussels<br>Belgium | Military Personnel Psychology | NAVPERSRANDCEN<br>Univ. of Minn.<br>ONRHQ<br>(Aug.-Oct. 85) | Richard E. Snow |
| Dr. Peter Nenniger<br>Seminar für Philosophie und Erziehungswissenschaft<br>Albert Ludwigs Universität<br>D-7800 Freiburg 1 BR<br>West Germany | Cognitive Psychology of Text Analysis | NPRDC, San Diego<br>(Aug or Sep 85)<br>Univ. of Illinois<br>(Sep 85)<br>Carnegie-Mellon Univ.<br>(Sep 85)<br>IBM System Research Center (Sep 85)<br>ONRHQ<br>(Oct 85) | Richard E. Snow |
| Paolo Mele<br>Università degli Studi di Roma "La Sapienza"<br>Facolta di Ingegneria<br>Dipartimento di Idraulica Trasporti e Strade (n 37)<br>Via Eudossiana<br>18-00184 Rome<br>Italy | Fluid Dynamics | DTNSRDC<br>(Sep 85)<br>NRL<br>(Sep 85)<br>ONRHQ<br>(Sep 85)<br>Mass. Inst. of<br>(Sep 85) | Patrick Leehey |

## SCIENCE NEWSBRIEFS FOR MARCH AND APRIL

The following issues of *Science Newsbrief* were published by the ONR, London, Scientific Liaison Division during March and April. *Science Newsbrief* provides concise accounts of scientific developments or science policy in Europe and the Middle East. Please request copies, by number, from ONR, London.

| *Science Newsbrief* Number | Title |
|---|---|
| 3-13 | UK's SERC Launches Research Initiative in Low-Dimensional Structures, by Paul Roman. |
| 3-14 | Israelis Generalize Einstein's Radiation Relations for Unbound Systems, by Paul Roman. |
| 3-15 | X-Ray Photon Factory Proposed by Israeli Scientist, by Paul Roman. |
| 3-19 | Aerodynamic Flow Modeling Research at Dornier in Germany, by CAPT L. Laddie Coburn, USN. |

## MARCH MAS BULLETINS

The following *Military Applications Summary (MAS) Bulletins* were published by the ONR, London, Military Applications Division during March. The *MAS Bulletin* is an account of naval developments in European research, development, test, and evaluation. Its distribution is limited to offices with the US Department of Defense. DoD organizations should request copies of the *Bulletins*, by number, from ONR, London.

| MASB Number | Title |
|---|---|
| 25-85 | Royal Navy Super Harrier Studies Underway |
| 27-85 | GEC Optical Fiber Couplers |
| 28-85 | UK Tornado Flies With Alarm Missiles |
| 29-85 | Turkish Naval Oceanography |
| 30-85 | Symposium on Low-Frequency Underwater Acoustics |
| 31-85 | Aircraft Anti-Runway Weapons Developments in Europe |
| 32-85 | Naval Oceanography in Israel |
| 33-85 | Satellite Data Collection and Platform Location (Users Conference) |
| 34-85 | First Quarterly Index 1985 |

## ONRL REPORT

To request the report, check the box on the self-addressed mailer and return it to ONR, London.

C-2-85 *Sixth International Conference on Fracture*, by Kenneth D. Challenger. The Sixth International Conference on Fracture was held in New Delhi, India, in December 1984. This report discusses work on the mechanisms of fracture, mechanics, fracture of nonmetallic materials, composites, and dynamic fracture. US and UK scientists and engineers are setting the pace for development in the field of fracture; but there are major research programs in Japan, Australia, France, West Germany, India, and China. The use of fracture mechanics for safety analysis and residual life estimation is widespread, but its use in design is still quite limited.



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